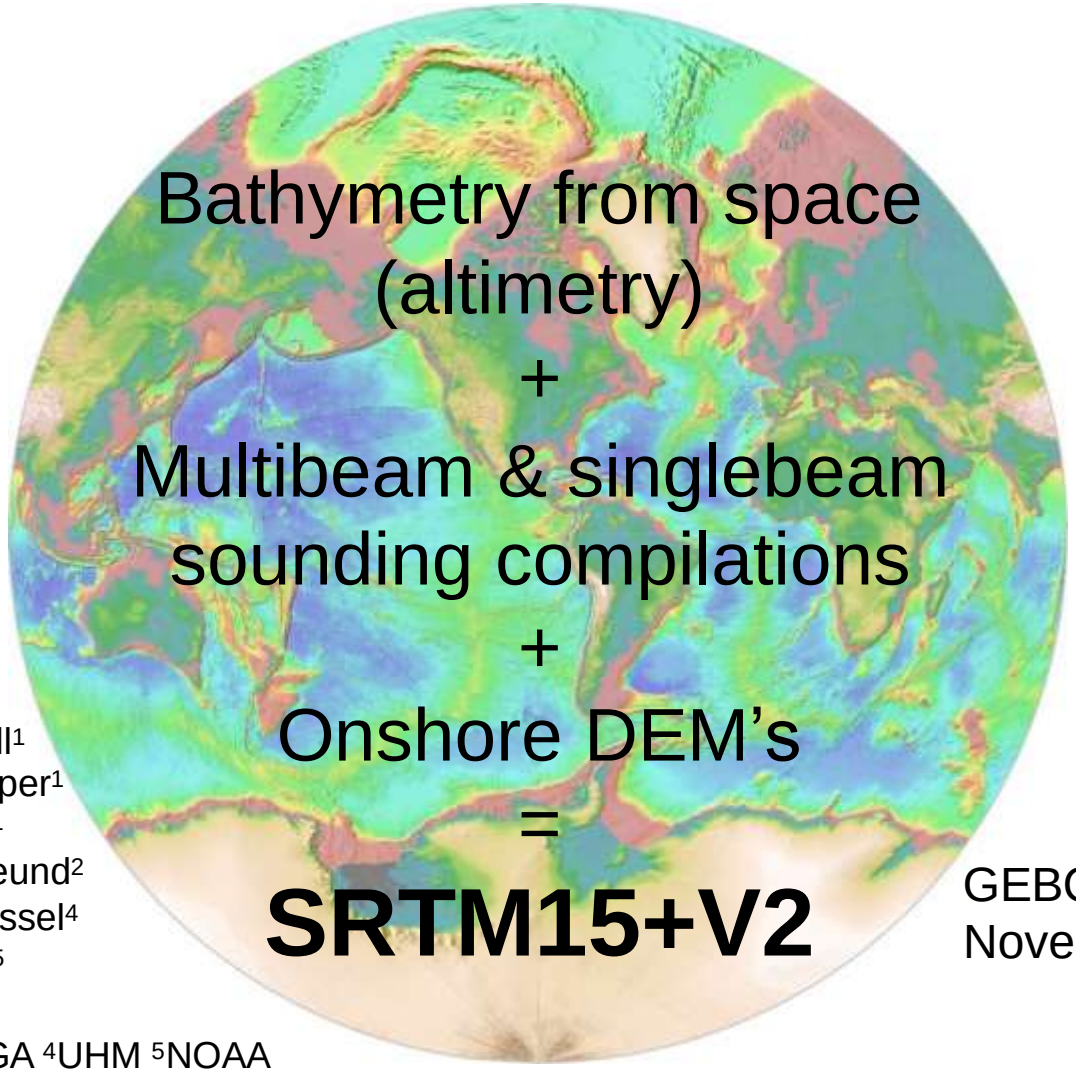


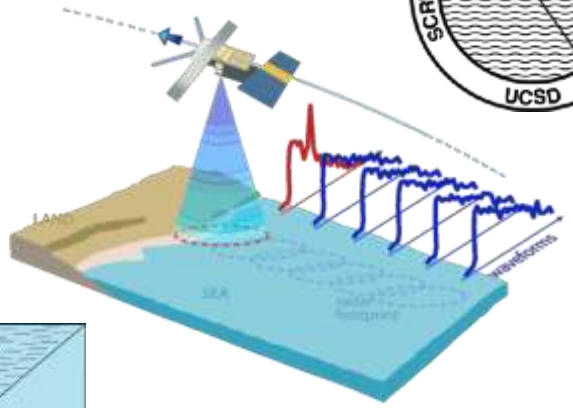
Bathymetry from space (altimetry)
+
Multibeam & singlebeam sounding compilations
+
Onshore DEM's
=
SRTM15+V2

B. Tozer[1] D. Sandwell[1]
J. J. Becker[1] Hugh Harper[1]
Christopher Olson[1]
Benjamin Tea[1] Yoav Freund[2]
James Beale[3] Paul Wessel[4]
Walter H. F. Smith[5]

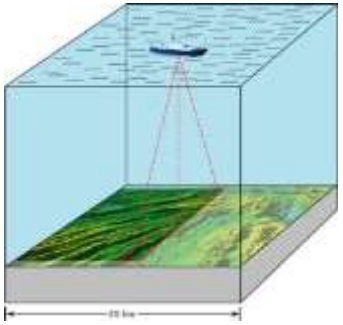
[1]IGPP, Scripps [2]UCSD [3]NGA [4]UHM [5]NOAA

GEBCO Symposium
November 14th 2018
Canberra

Outline



Part one: ***New satellite altimetry***



Part two: ***New bathymetry***

Part three: ***SRTM15+V2***

Part four: ***Future plans & grid integration***

Satellite altimetry

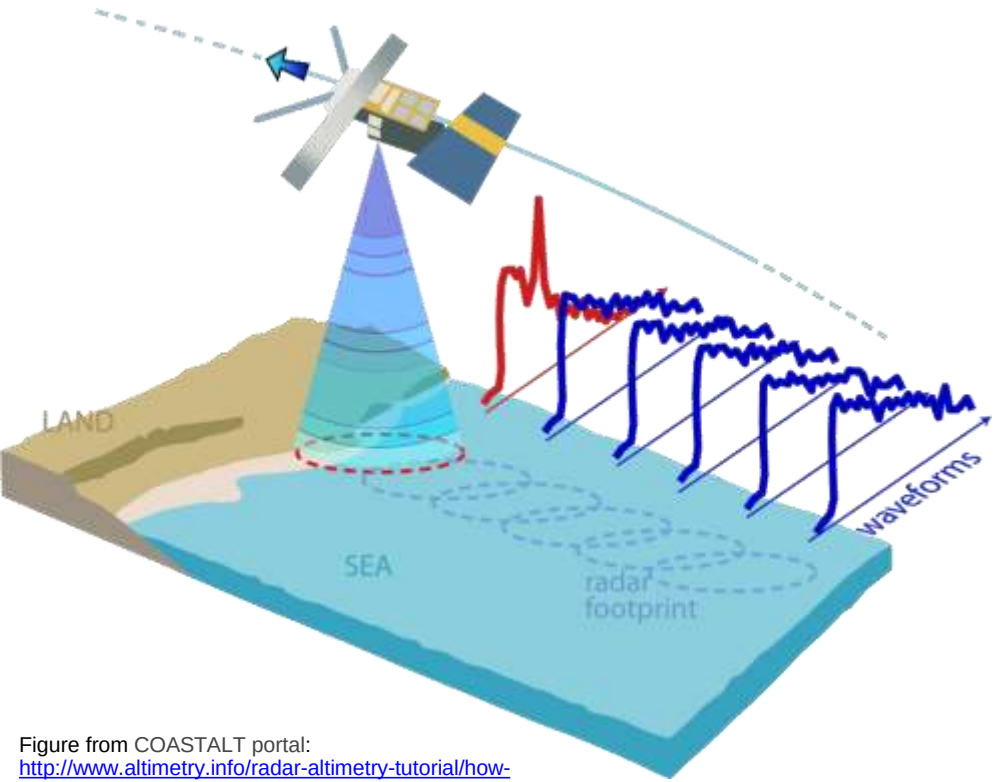


Figure from COASTALT portal:
http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/

Sea surface slope

↓

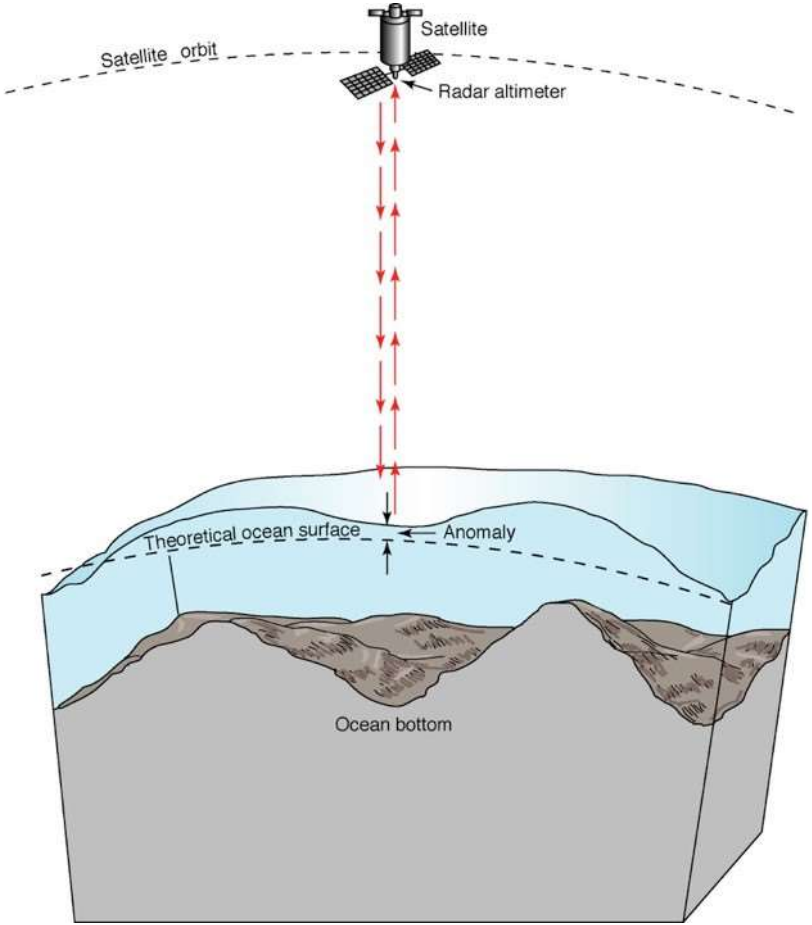
Gravity anomaly

↓

Predicted bathymetry

NB: We're primarily focused on the deep oceans for plate tectonic applications

Satellite altimetry



Sea surface slope

↓

Gravity anomaly

↓

Predicted bathymetry

The aim of the game is to measure **sea surface slope as accurately as possible**.

Satellite altimetry

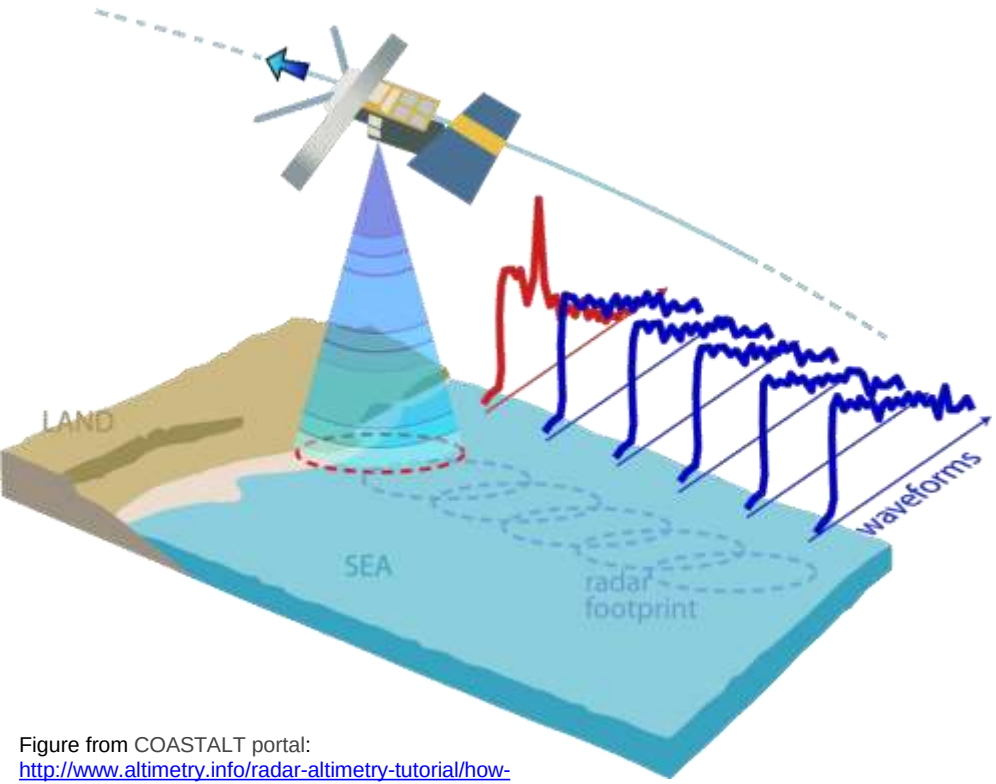


Figure from COASTALT portal:
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Sea surface slope

↓

Gravity anomaly

↓

Predicted bathymetry

The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two main parameters:

Satellite altimetry

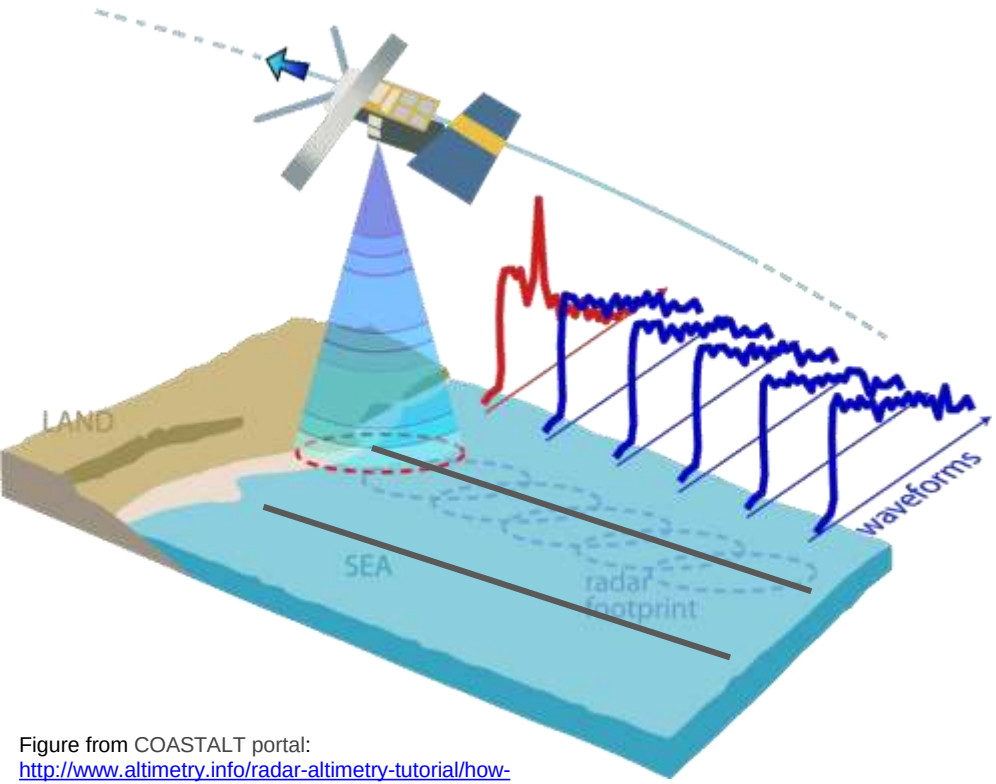

Figure from COASTALT portal: http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/

Sea surface slope

↓

Gravity anomaly

↓

Predicted bathymetry

The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two main parameters:

1. Density of track spacing.

Satellite altimetry

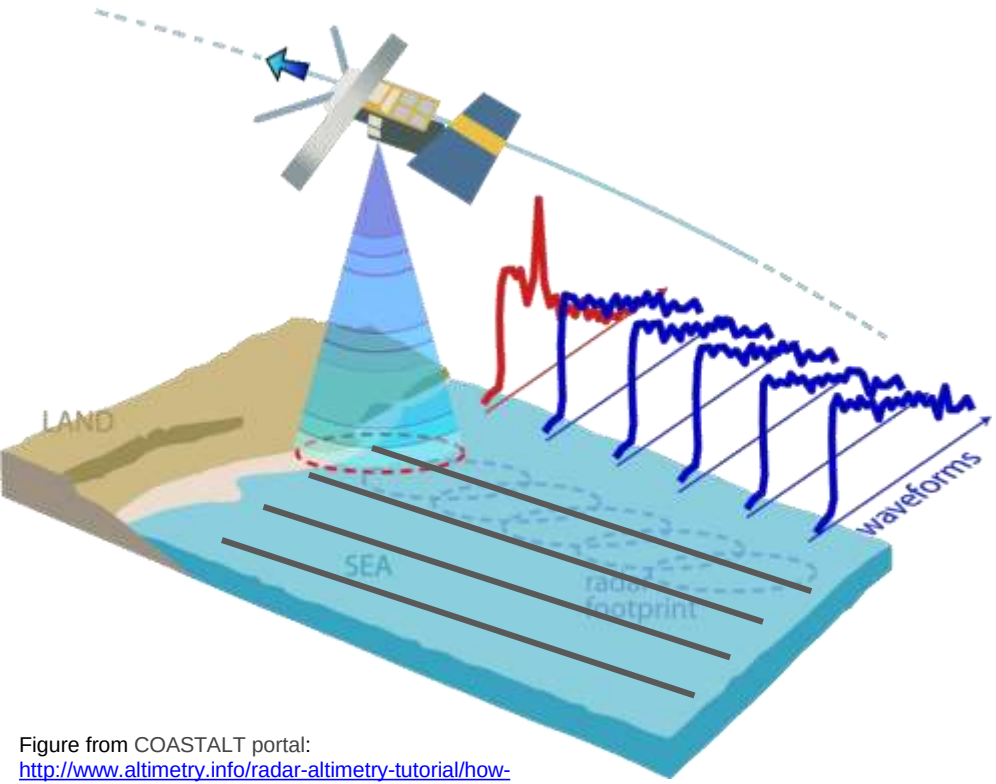

Figure from COASTALT portal: http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/

Sea surface slope

↓

Gravity anomaly

↓

Predicted bathymetry

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Satellite altimetry

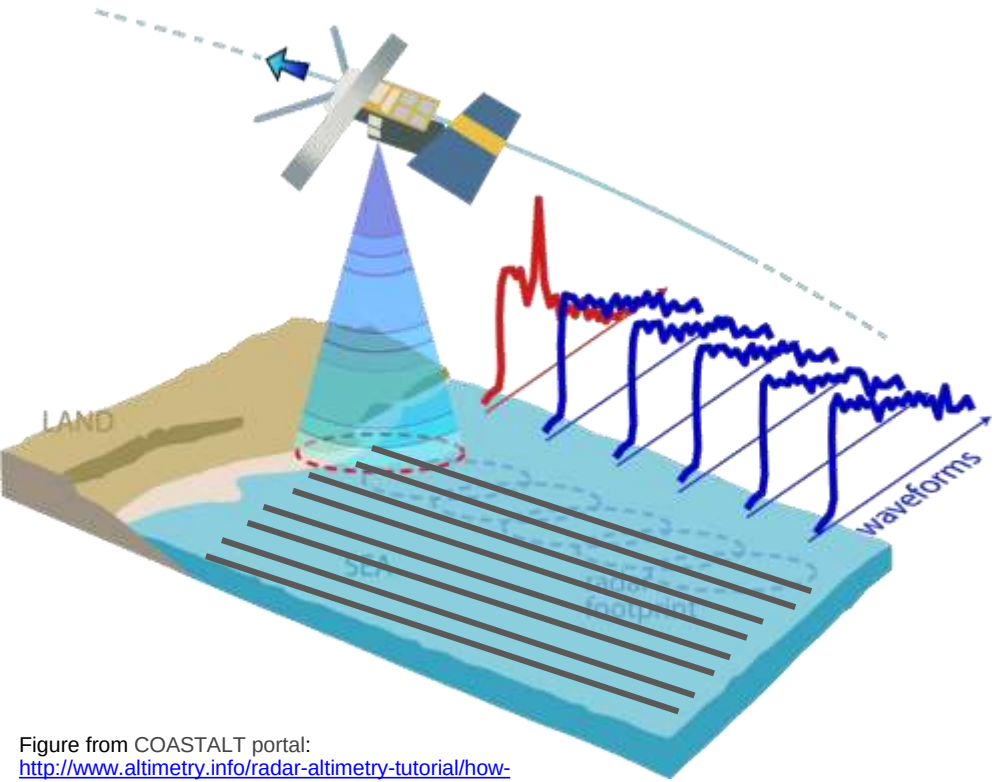


Figure from COASTALT portal:
http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/

Sea surface slope
↓
Gravity anomaly
↓
Predicted bathymetry

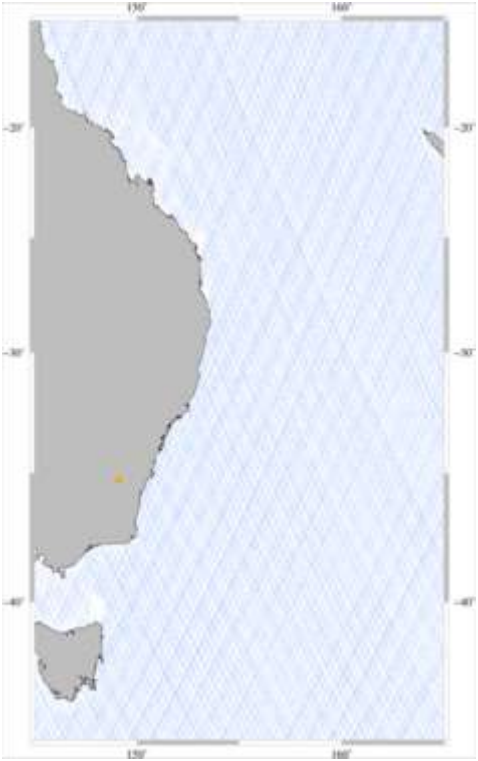
The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two main parameters:

1. Density of track spacing
   (& inclination - currently poor E-W component)

Track density

Geosat

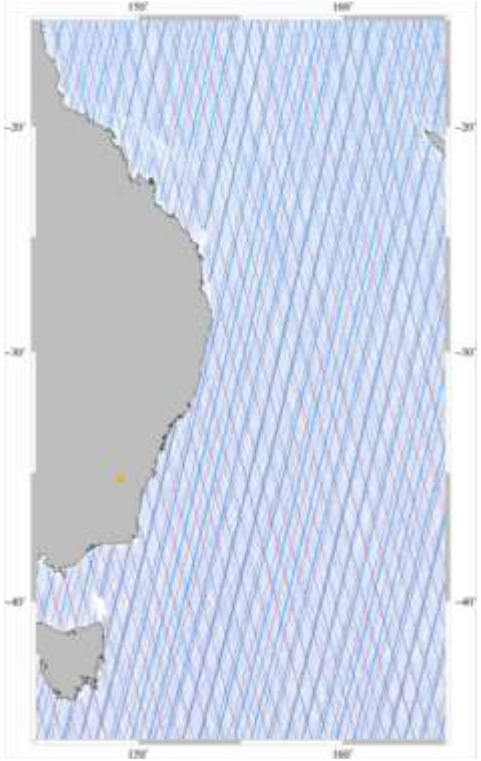


Track density

Geosat + **ers1**

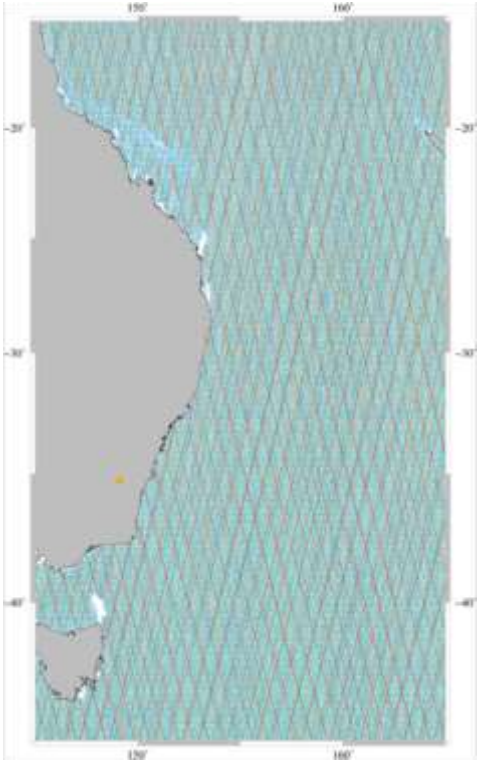
Track density

Geosat + ers1 + **envisat**



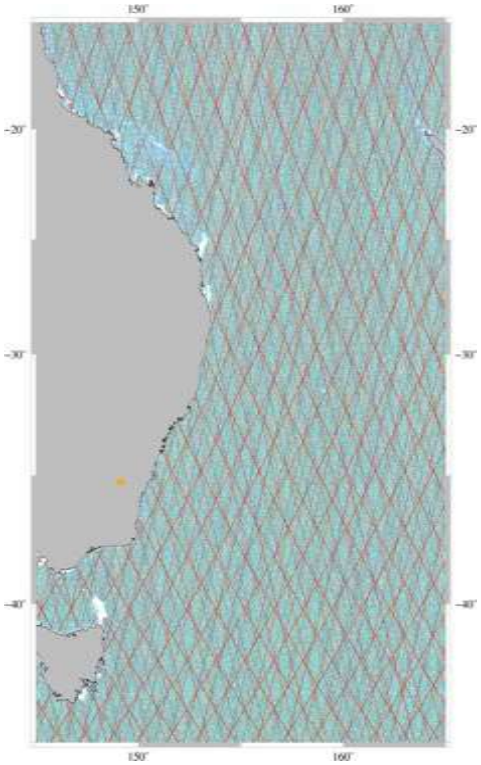
Track density

Geosat + ers1 + envisat
+ **Cyrosat-2**



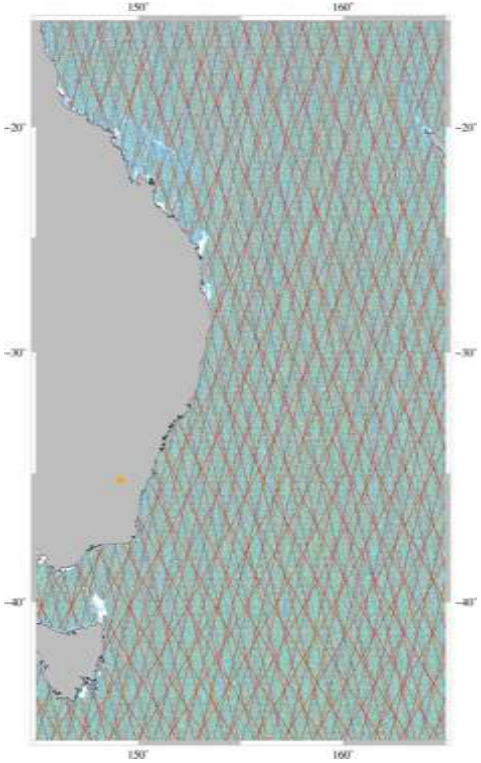
Track density

Geosat + ers1 + envisat
+ Cyrosat-2 + **Jason-1**



Track density

Geosat + ers1 + envisat + Cyrosat-2 + Jason-1 + **AltiKa**



Satellite altimetry

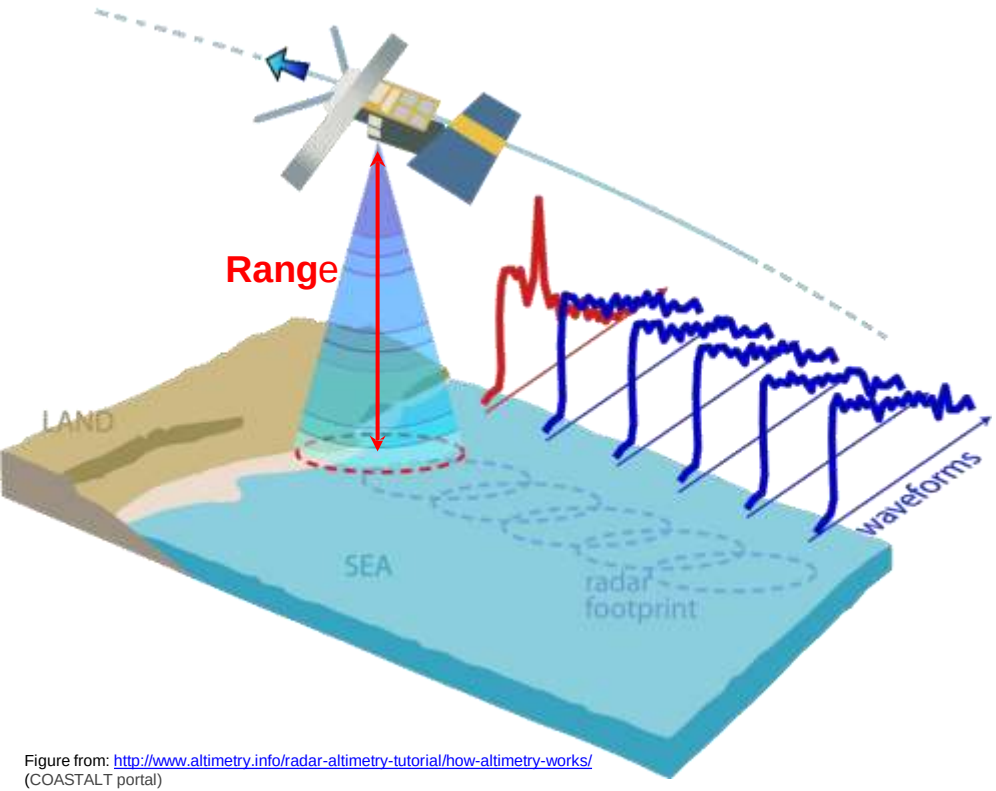


Figure from: http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/
(COASTALT portal)

Sea surface slope

↓

Gravity anomaly

↓

Predicted bathymetry

The aim of the game is to measure **sea surface slope as accurately as possible**.

This relies on two parameters:

1. Density of track spacing.

1. Range precision (i.e., satellite-to-surface distance, determined from echo time).

Range precision

Altimeter	Range precision @ 20 Hz (mm)
Geosat	57.0
ERS-1	61.8
Envisat	51.8
Jason-1	46.4
CryoSat-2 LRM	42.7
CryoSat-2 SAR	49.7
AltiKa	**20.5**

AltiKa is **2x more precise** than all previous altimeters

Smith [2015] showed standard GDR of AltiKa is 2 X more precise than Envisat

Zhang and Sandwell [2016] showed that AltiKa also benefits from 2-pass retracking.

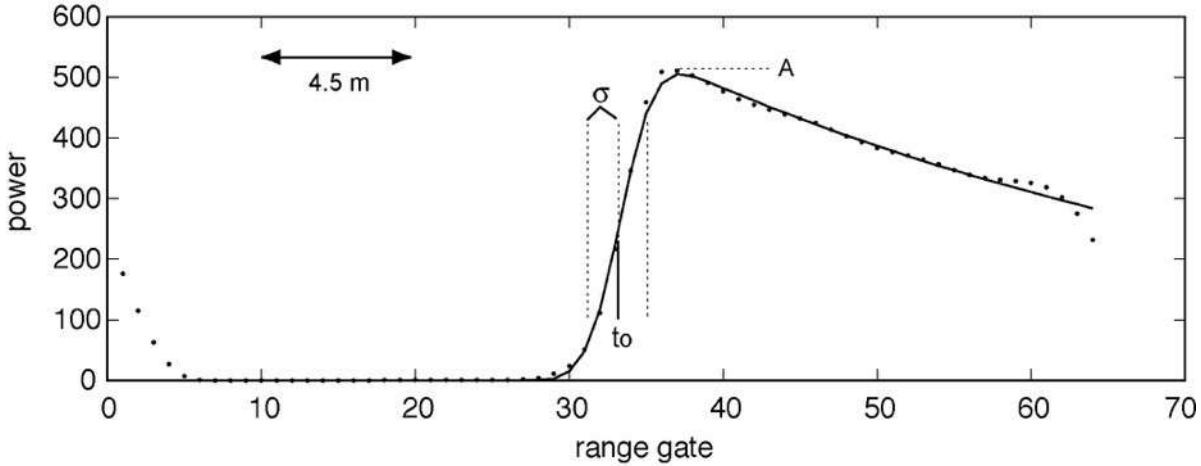
In July 2016 AltiKa began geodetic mapping. Could achieve 1 mGal global marine gravity.

AltiKa 4.5 mm @ 1 Hz

Waveform retracking

largest error source in measuring the sea surface slope is from errors **picking the arrival time of return echo**

2-pass waveform retracking improves range precision



Estimate 3 parameters: arrival time (t_o), rise time (σ), and power (A).

$$M(t) = \frac{A}{2}\{1 + erf(\eta)\}; \qquad \eta = \frac{t - t_o}{\sqrt{2}\sigma}$$

Retrack waveforms with standard 3-parameter model

1) Smooth rise time over 45-km

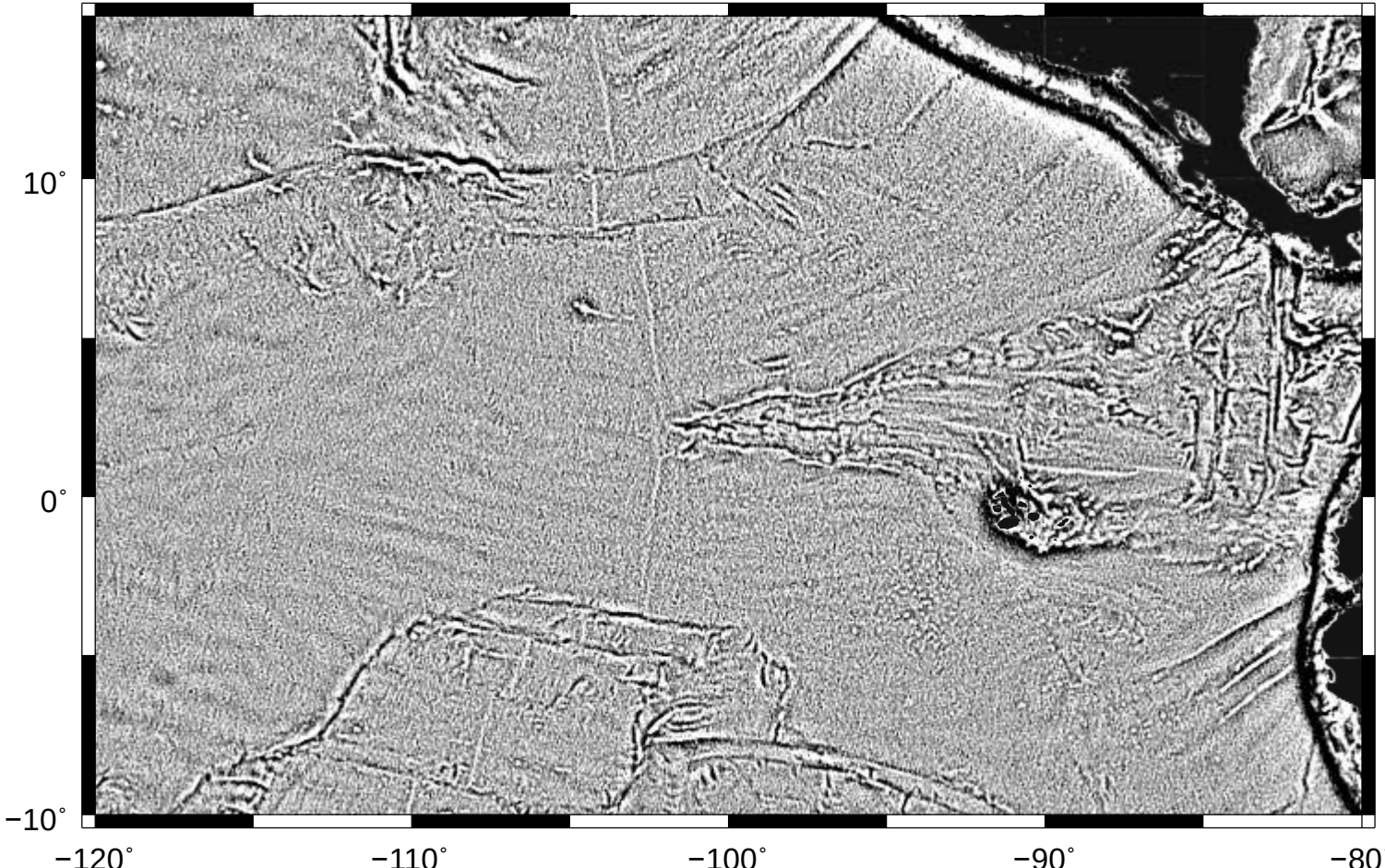
2) Retrack waveforms with 2-parameter model

Note: this assumes wave height varies smoothly along track. [*Sandwell and Smith*, 2005]

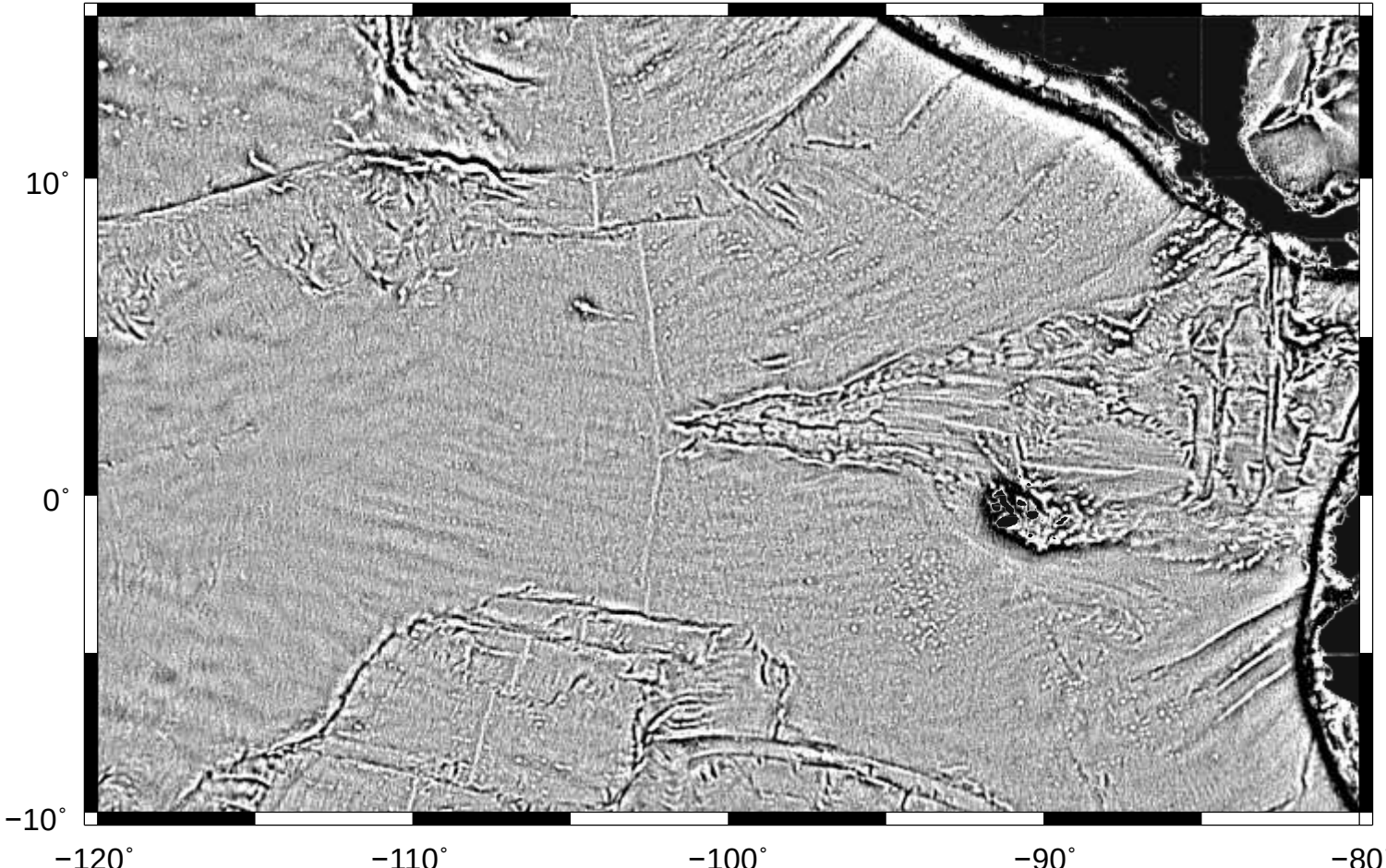
AltiKa: Zhang & Sandwell (2016)

Jason-2: Harper & Sandwell (In progress)

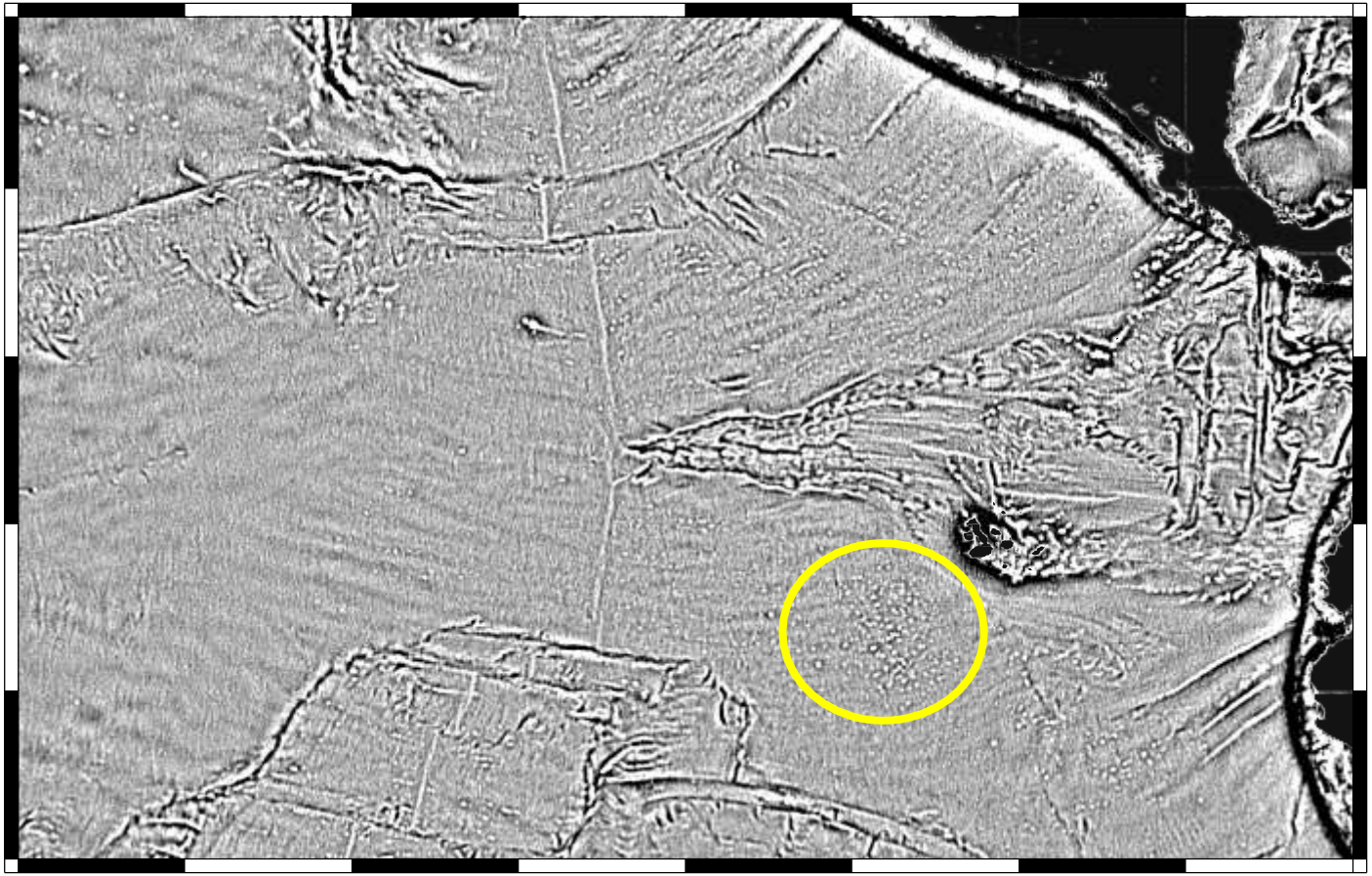
VGG (V18) Geosat + ERS



VGG (V24)

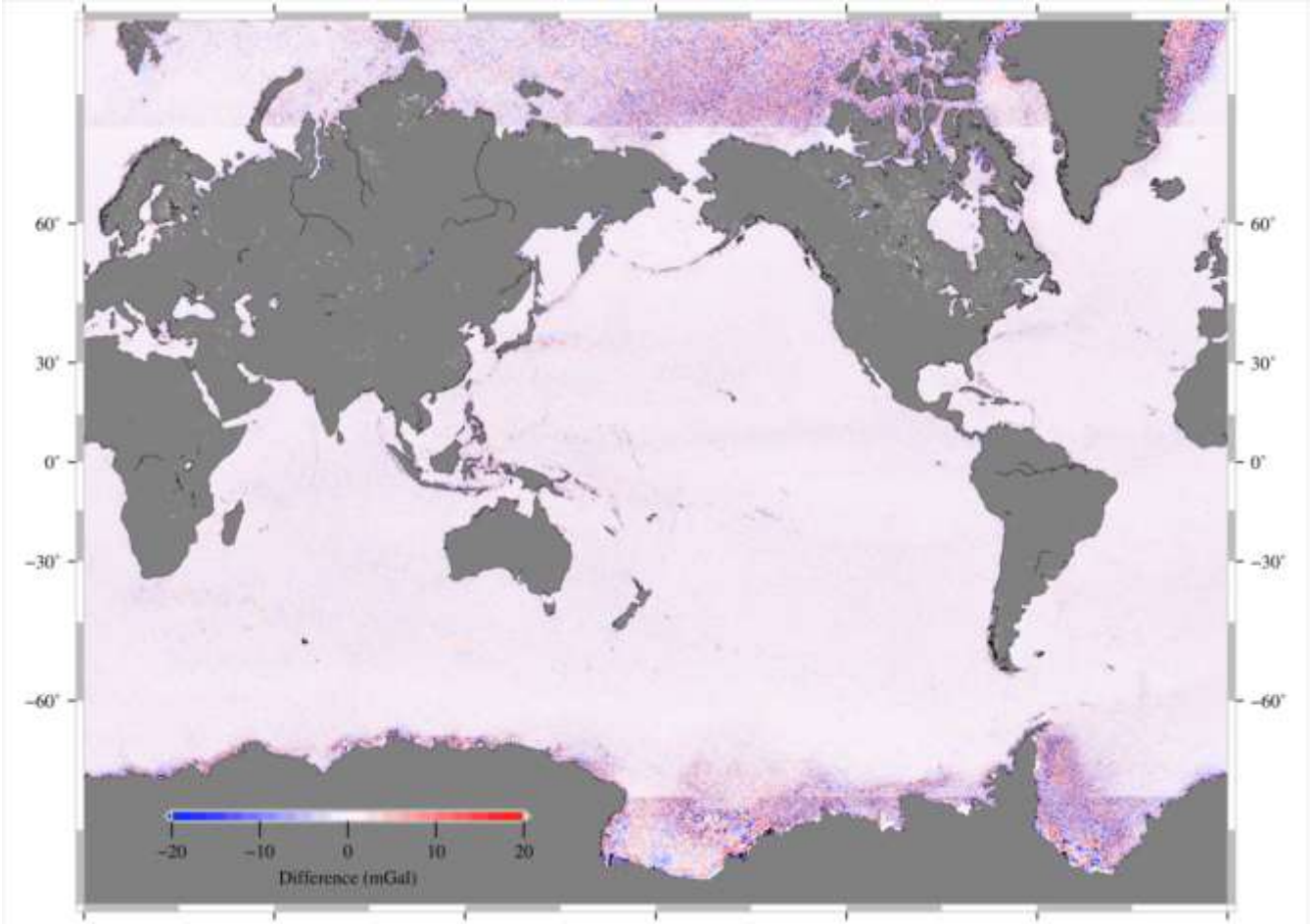


VGG (V27) + CryoSat + AltiKa + Jason-1



Free-air anomaly: change V24-V18

Statistic	change (mGal)
Mean	-0.05
Standard Dev.	2.92



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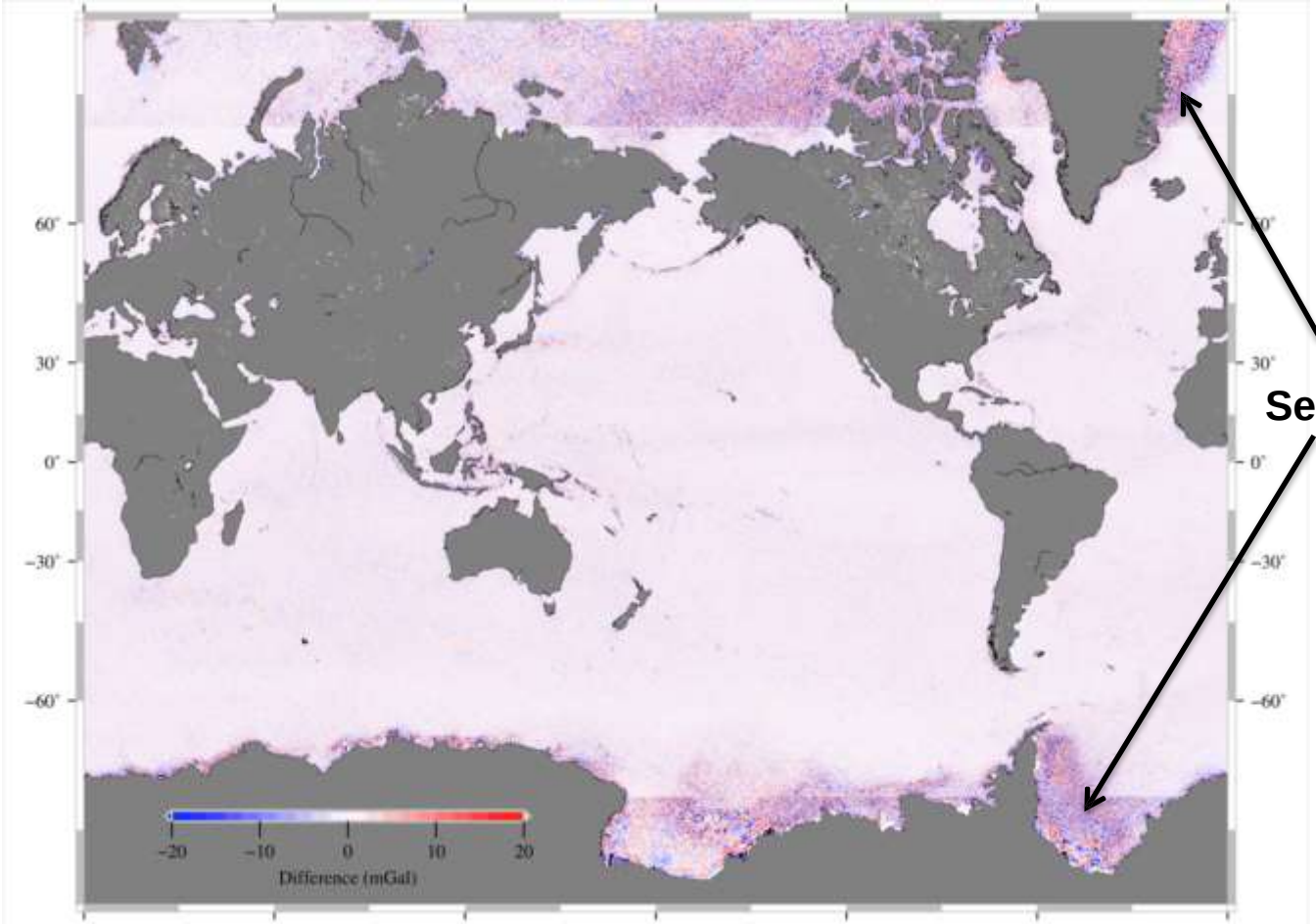
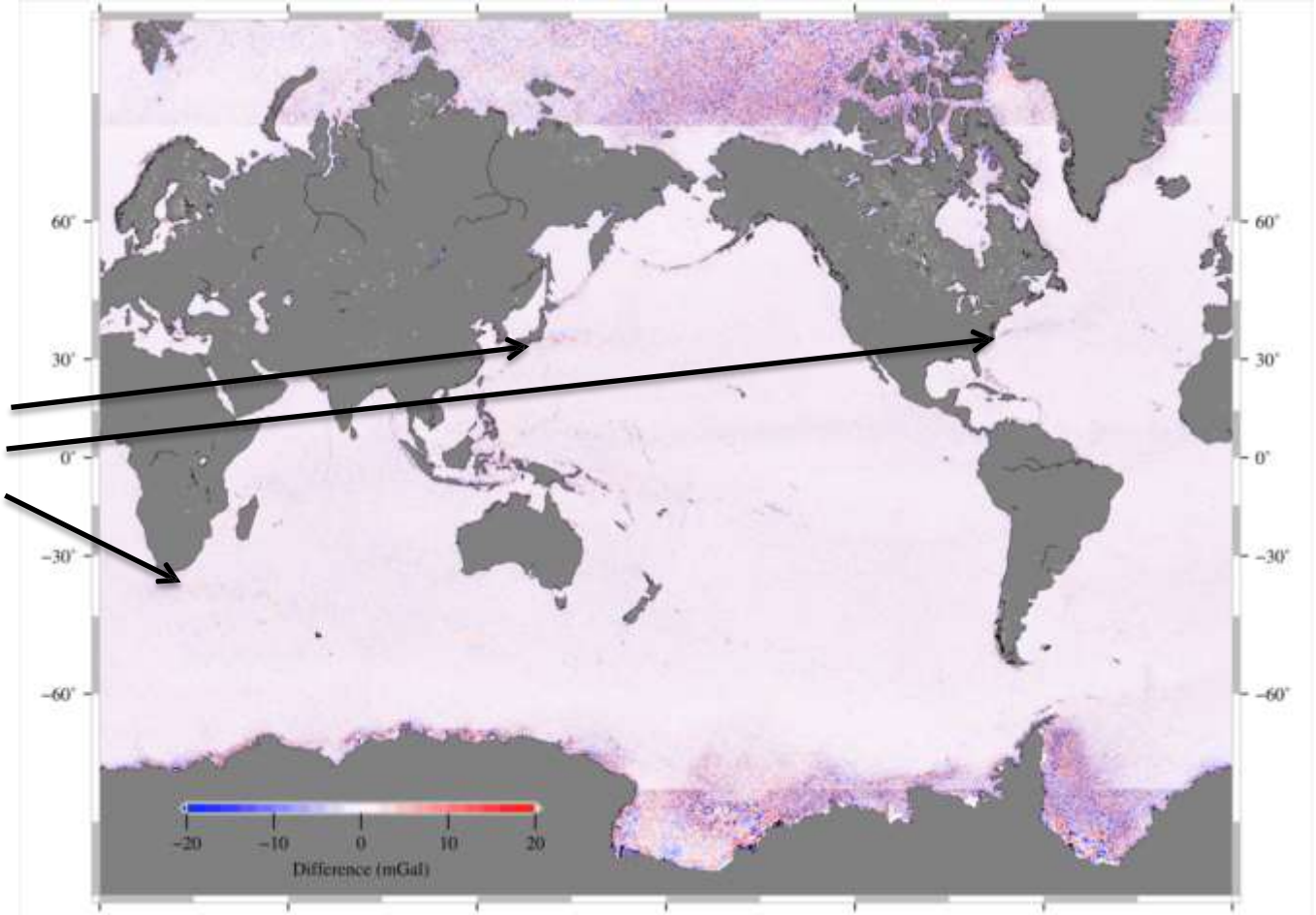
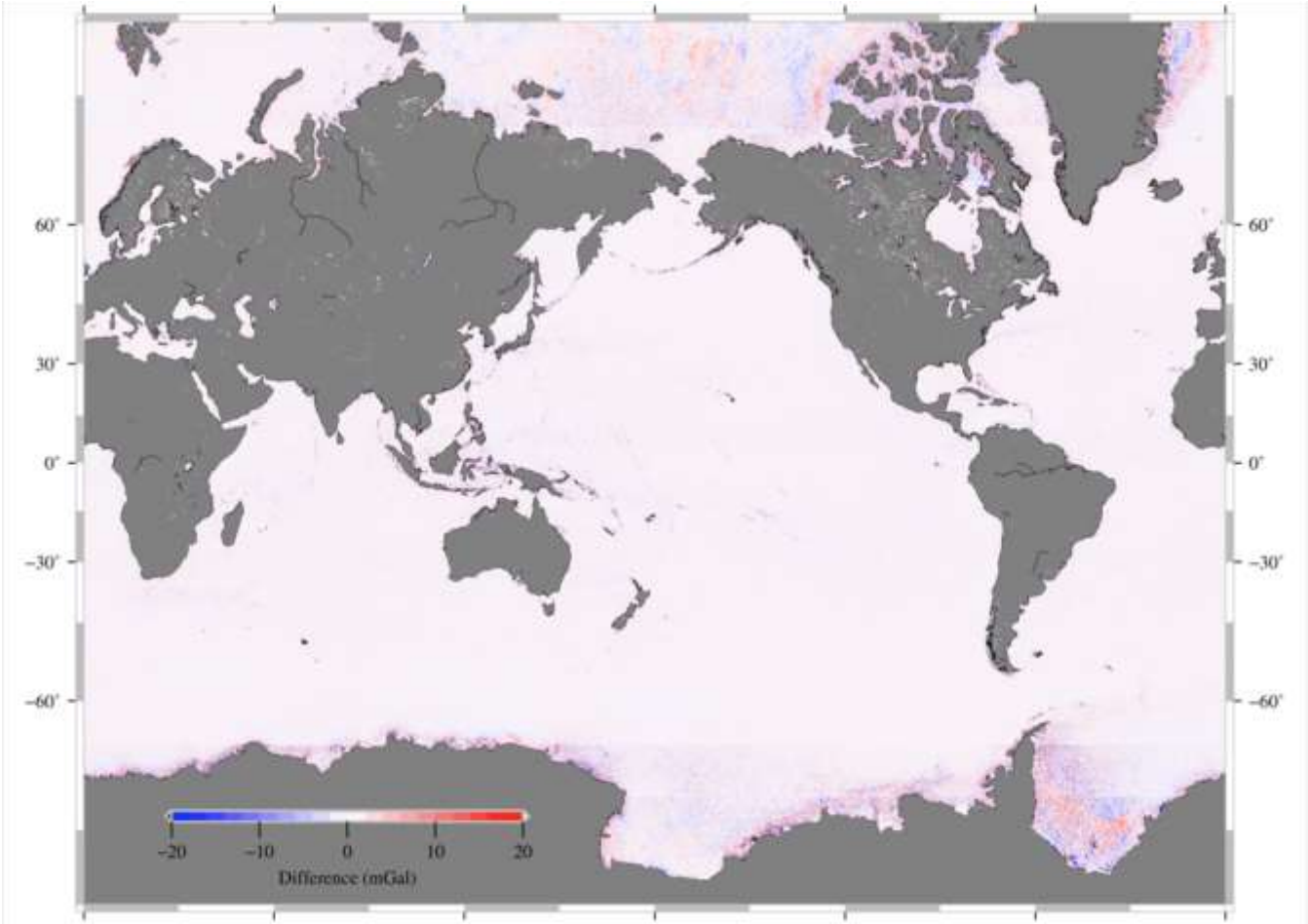


Free-air anomaly: change V24-V18

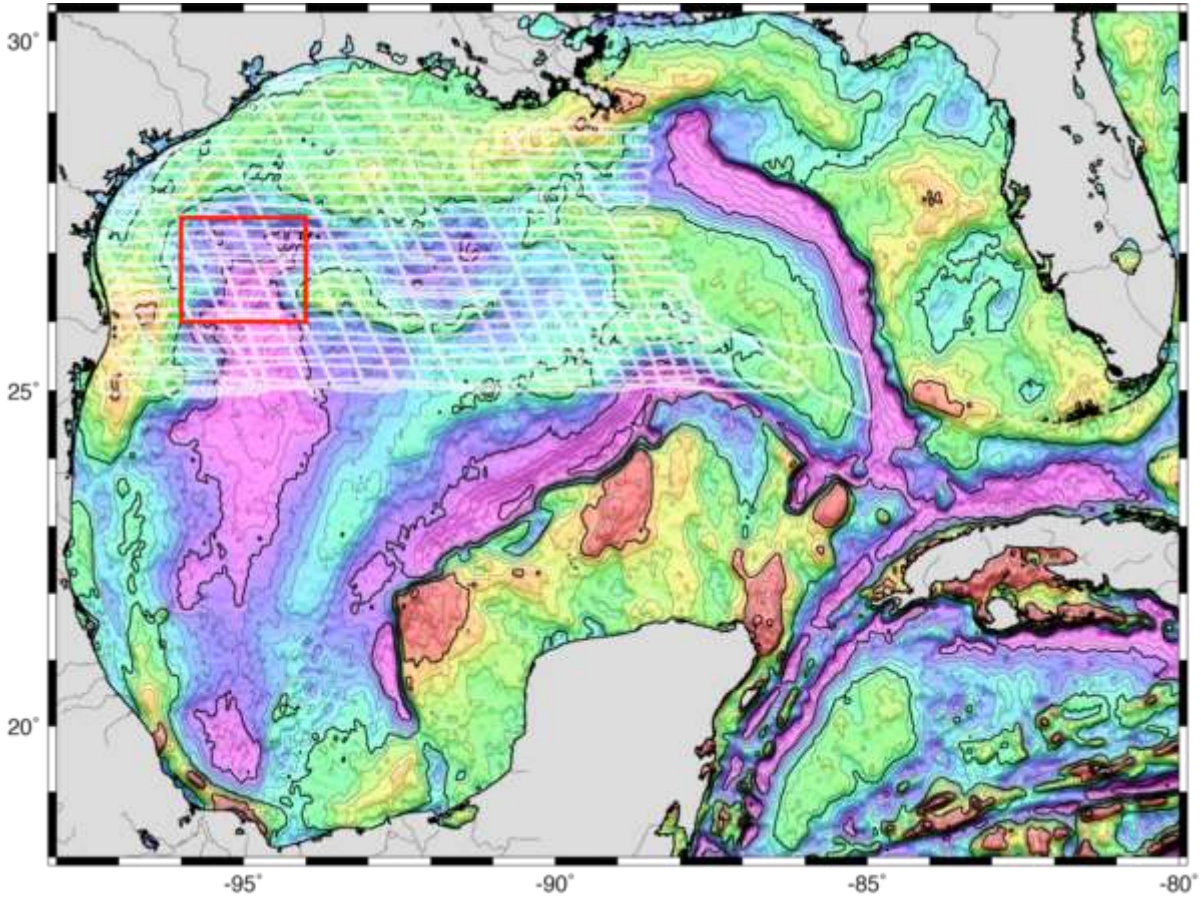


Free-air anomaly: change V27-V24

Statistic	change (mGal)
Mean	-0.04
Standard Dev.	1.82



Accuracy – how much are we improving?



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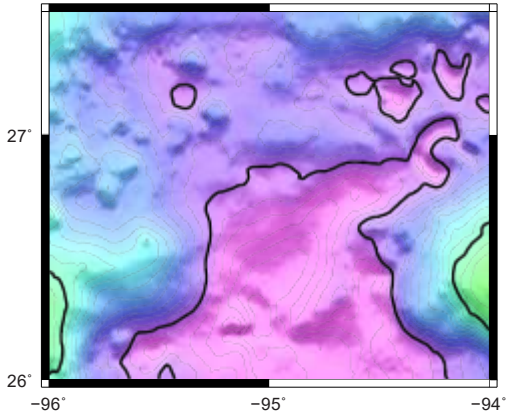
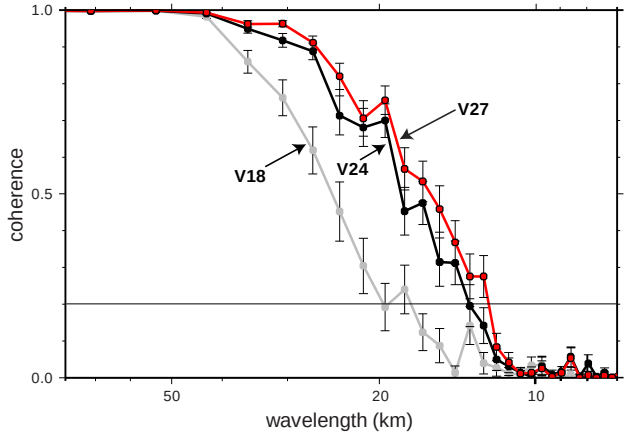
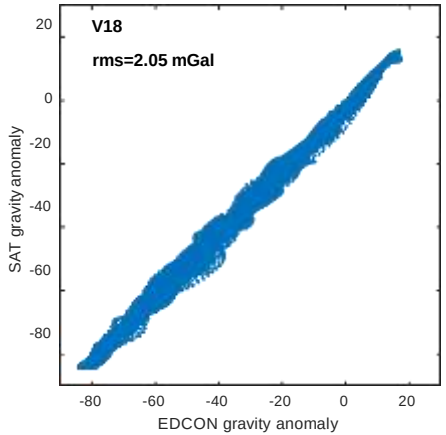
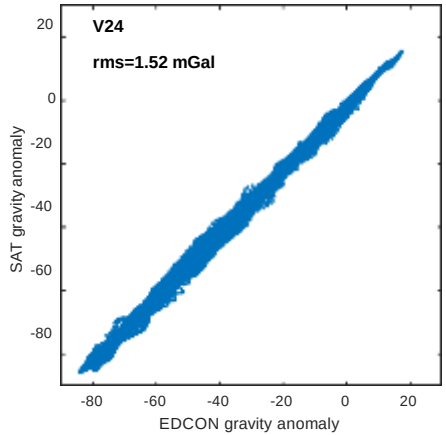
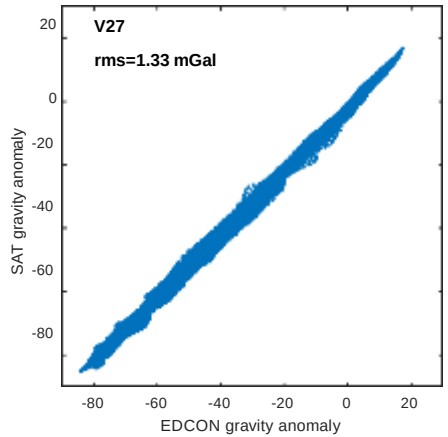










Limit on spatial resolution

$$g(k,z) = g(k,0)\, e^{-2\pi kz}$$

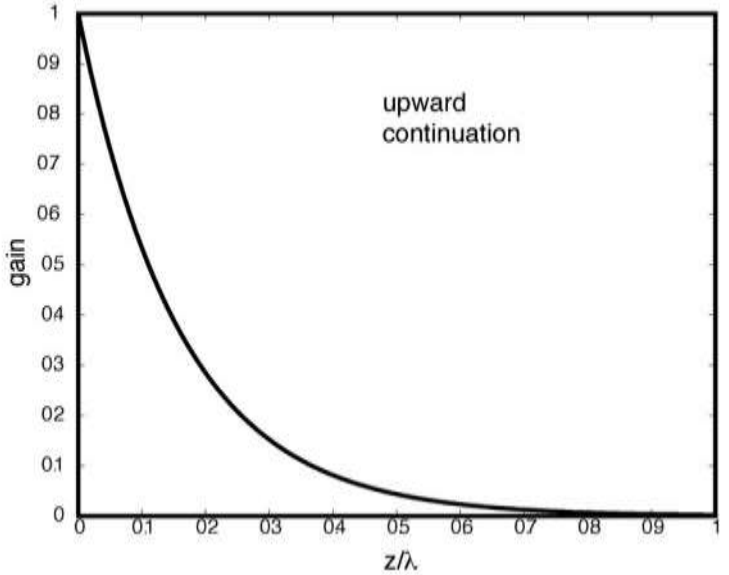
gravity at altitude

gravity at seafloor

X

upward continuation

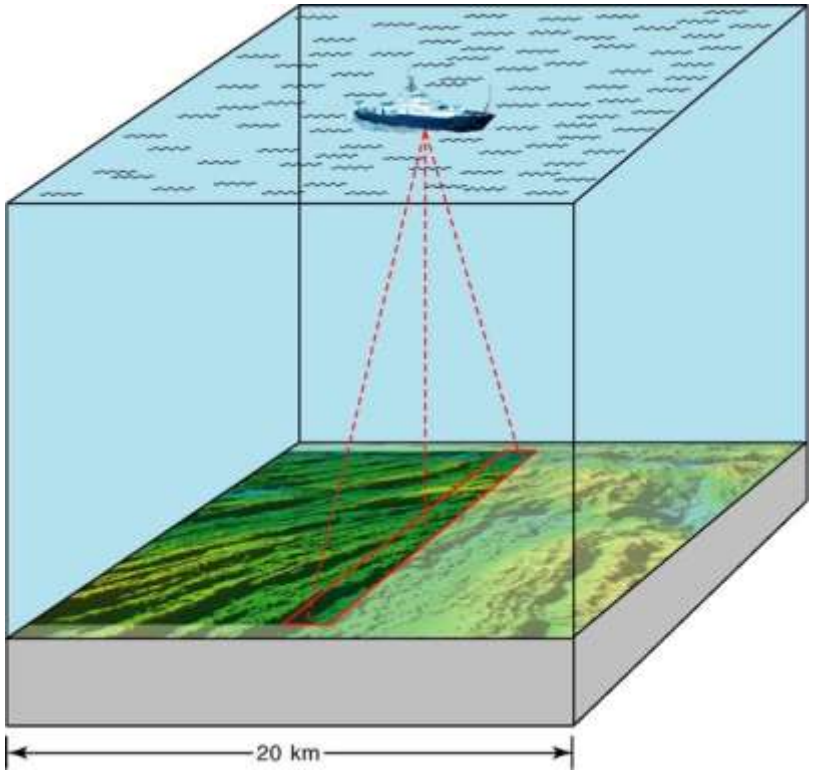
	$\lambda=1/k$	z	gain
shallow margin	2 km	1 km	0.043
deep ocean	8 km	4 km	0.043
GOCE altitude	8 km	200 km	10^{-68}



Shipboard bathymetry

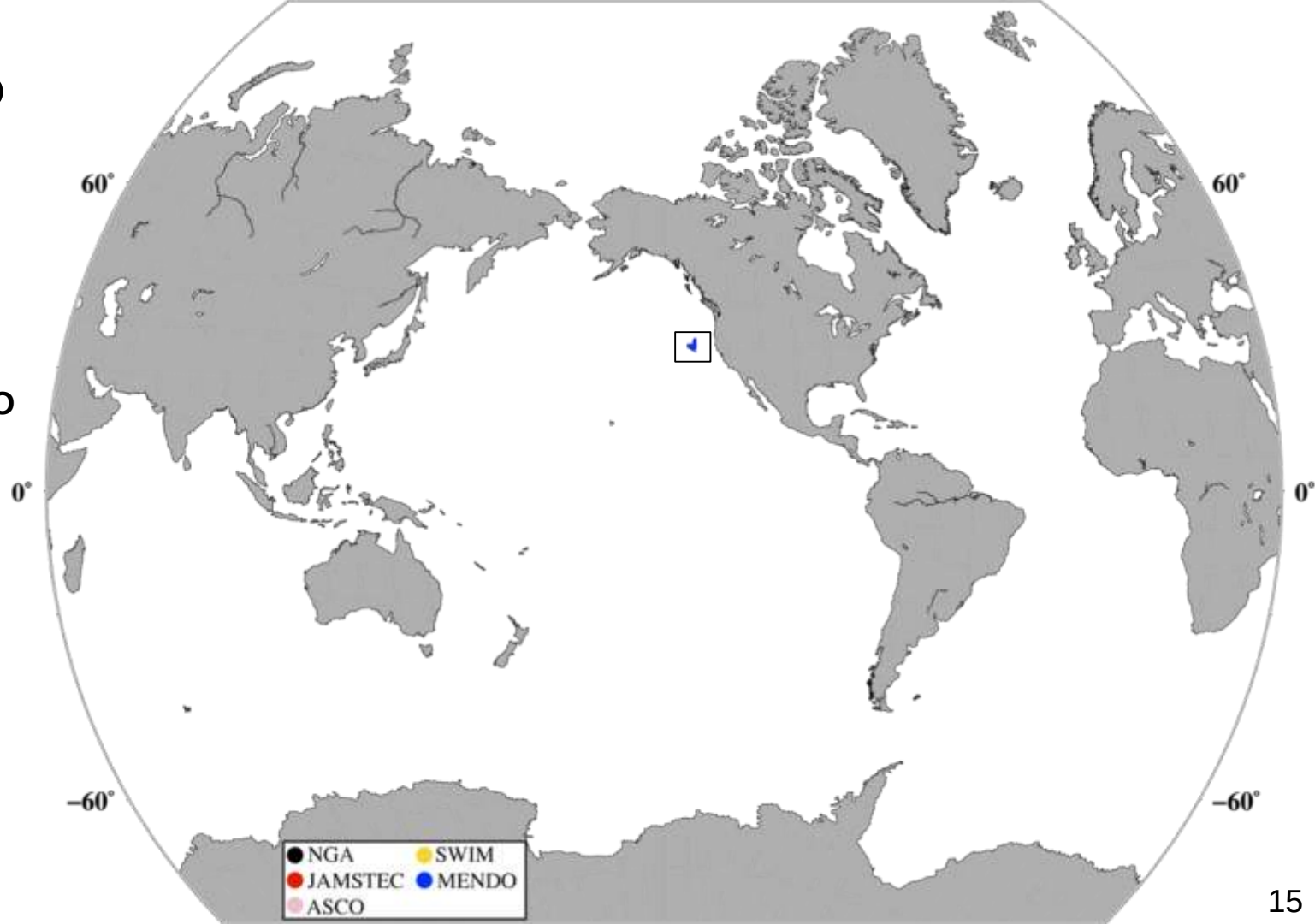
SRTM15+ V2: New datasets (2014-2018)

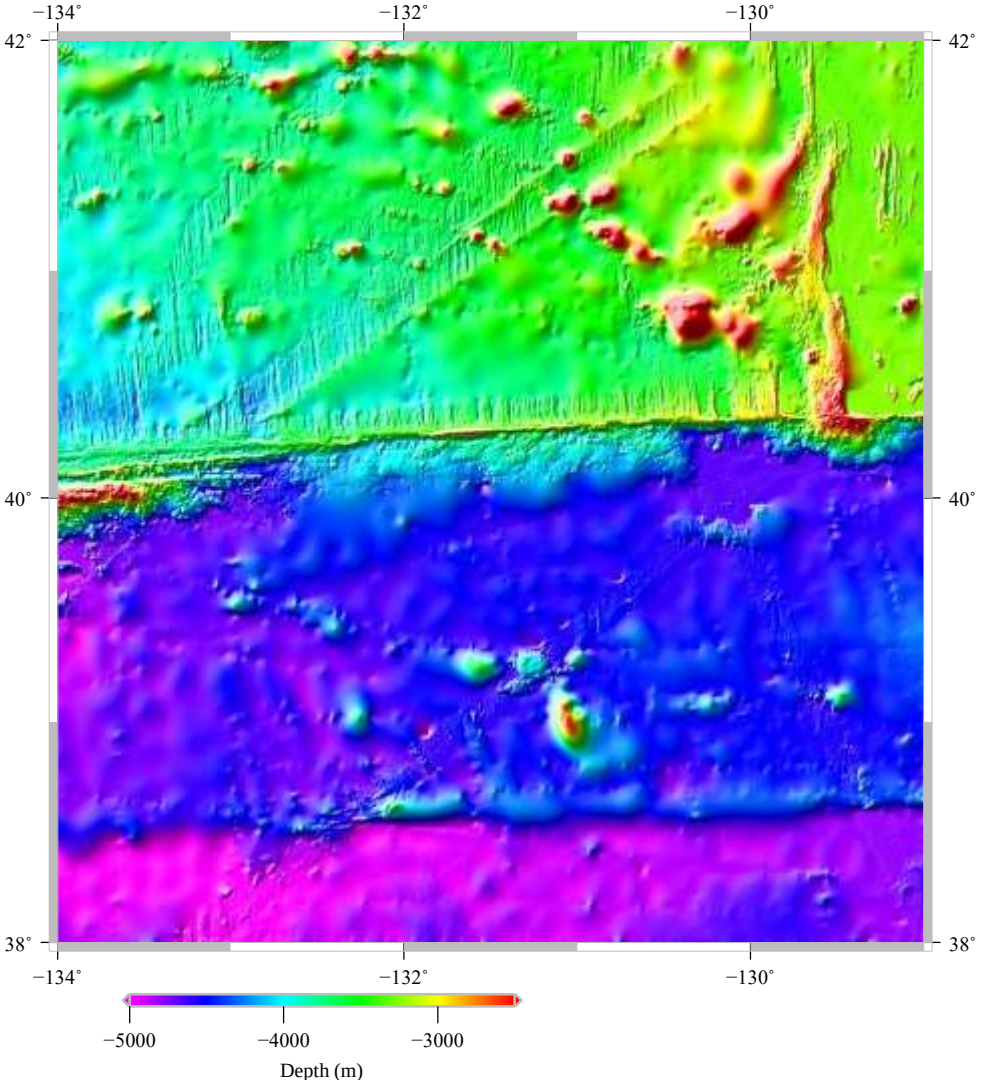
- *Mendocino*
- *SWIM*
- *ASCO (MH370)*
- *JAMSTEC 2012-2016*
- *NGA “unclassified”*
- *IBCAO V3 (north of 80° N)*

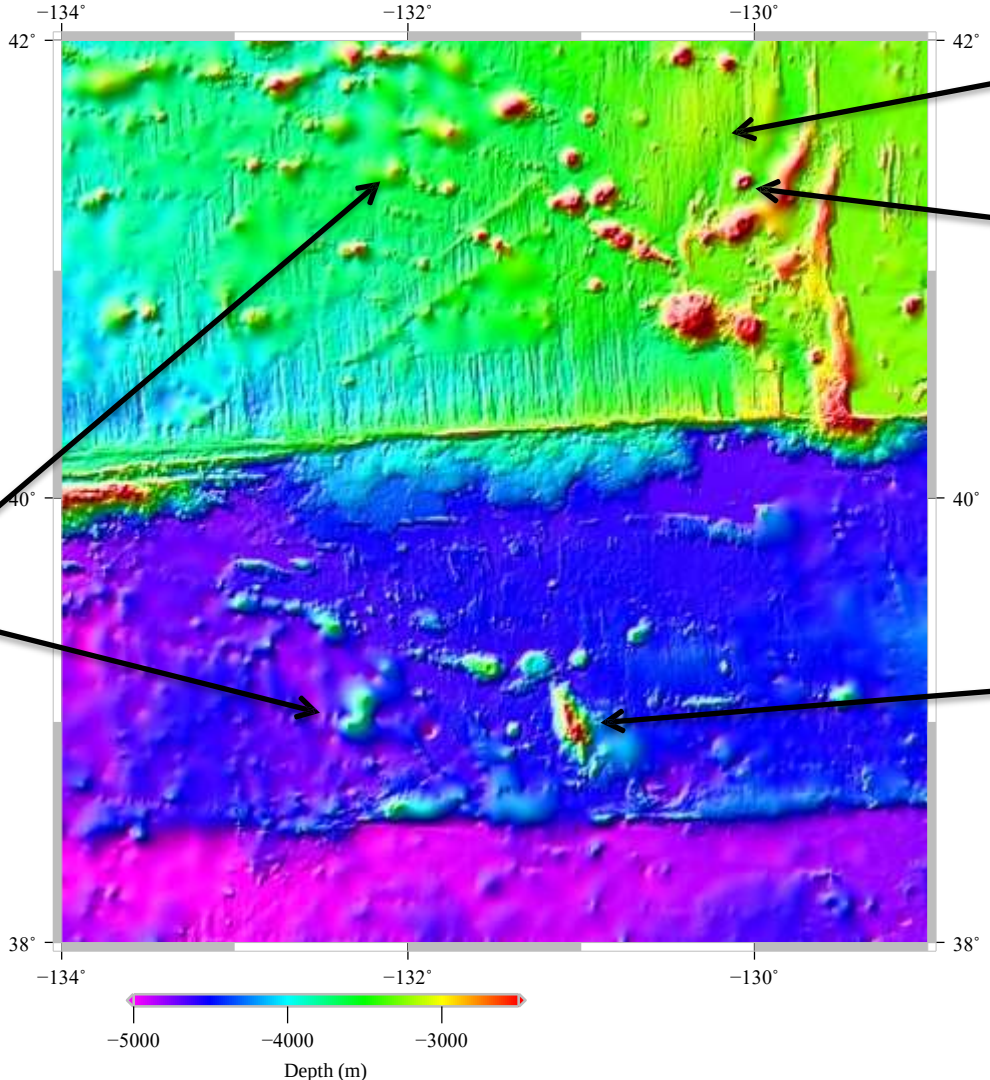


Mendocino

- Three multibeam surveys
- From **CCOM & SIO**
- Raw data
  - Cleaned




−134°
−132°
−130°
42°
40°
38°
−5000
−4000
−3000
Depth (m)

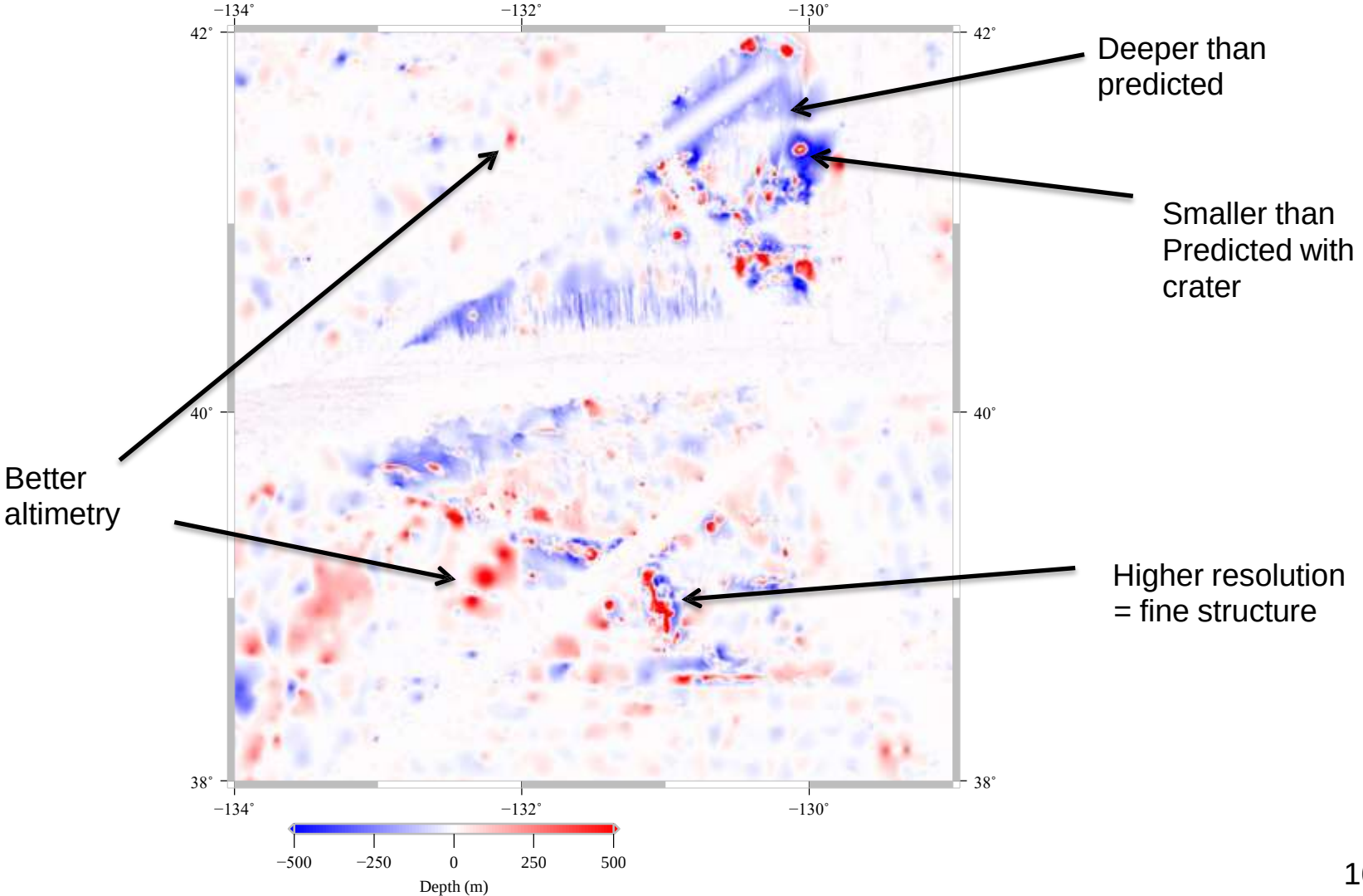


Deeper than predicted

Smaller than Predicted with crater

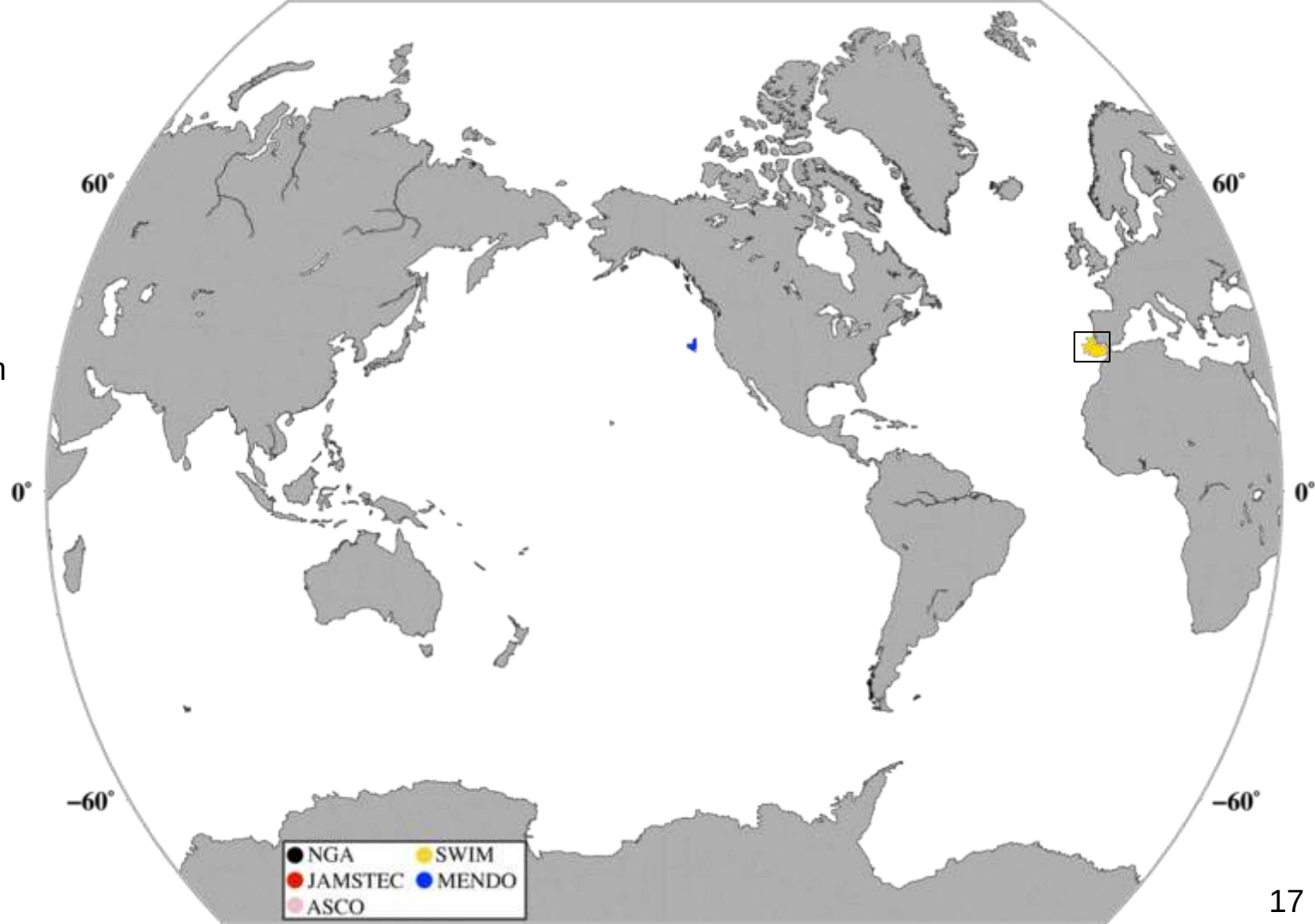
Better altimetry

Higher resolution = fine structure


Deeper than predicted
Smaller than Predicted with crater
Better altimetry
Higher resolution = fine structure
−134˚
−132˚
−130˚
42˚
40˚
38˚
−500
−250
0
250
500
Depth (m)

SWIM

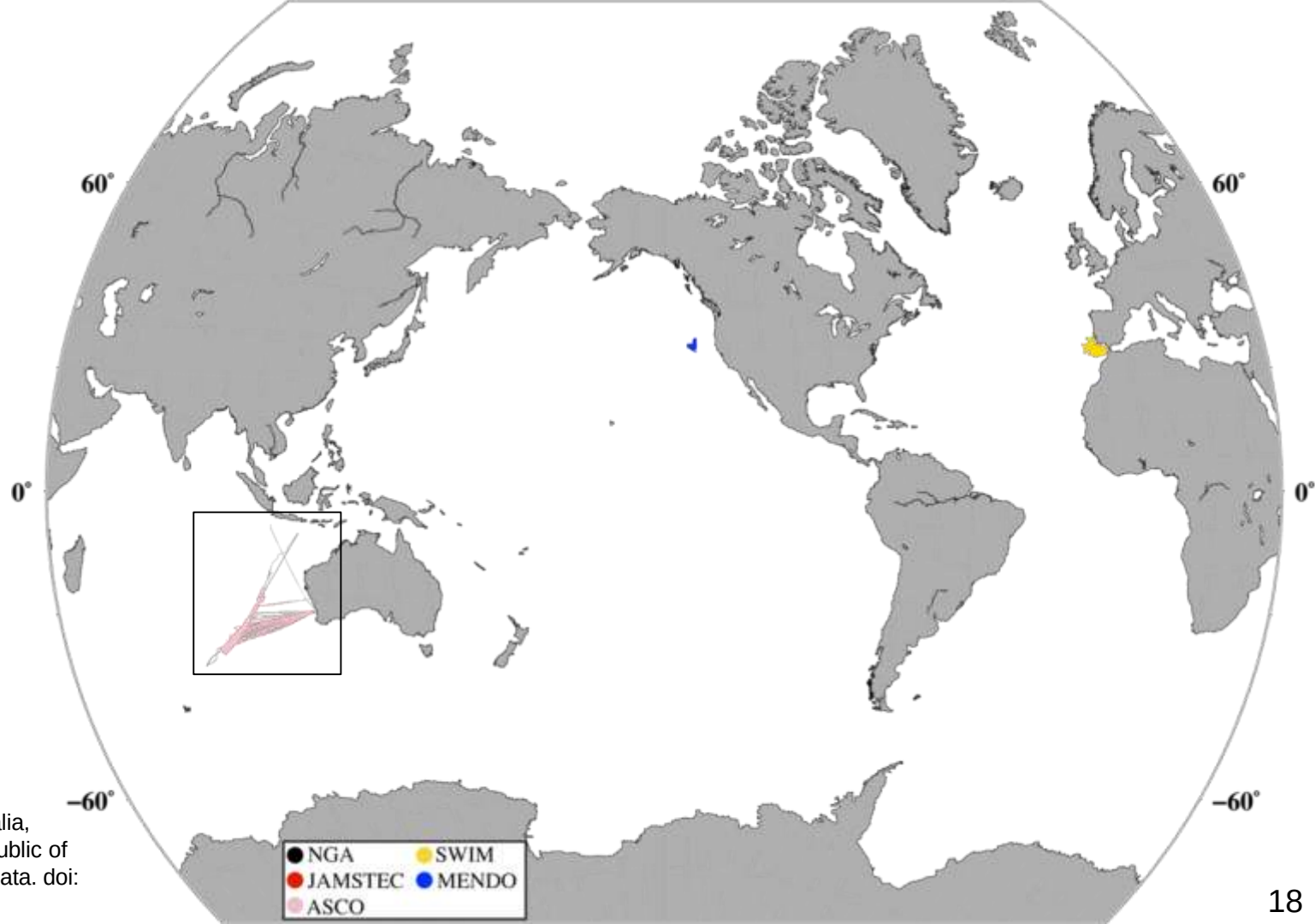
- SW Iberia
- Multiple multibeam cruises merged
- Gridded dataset
  -clean



Diez et al., (2005)

MH370

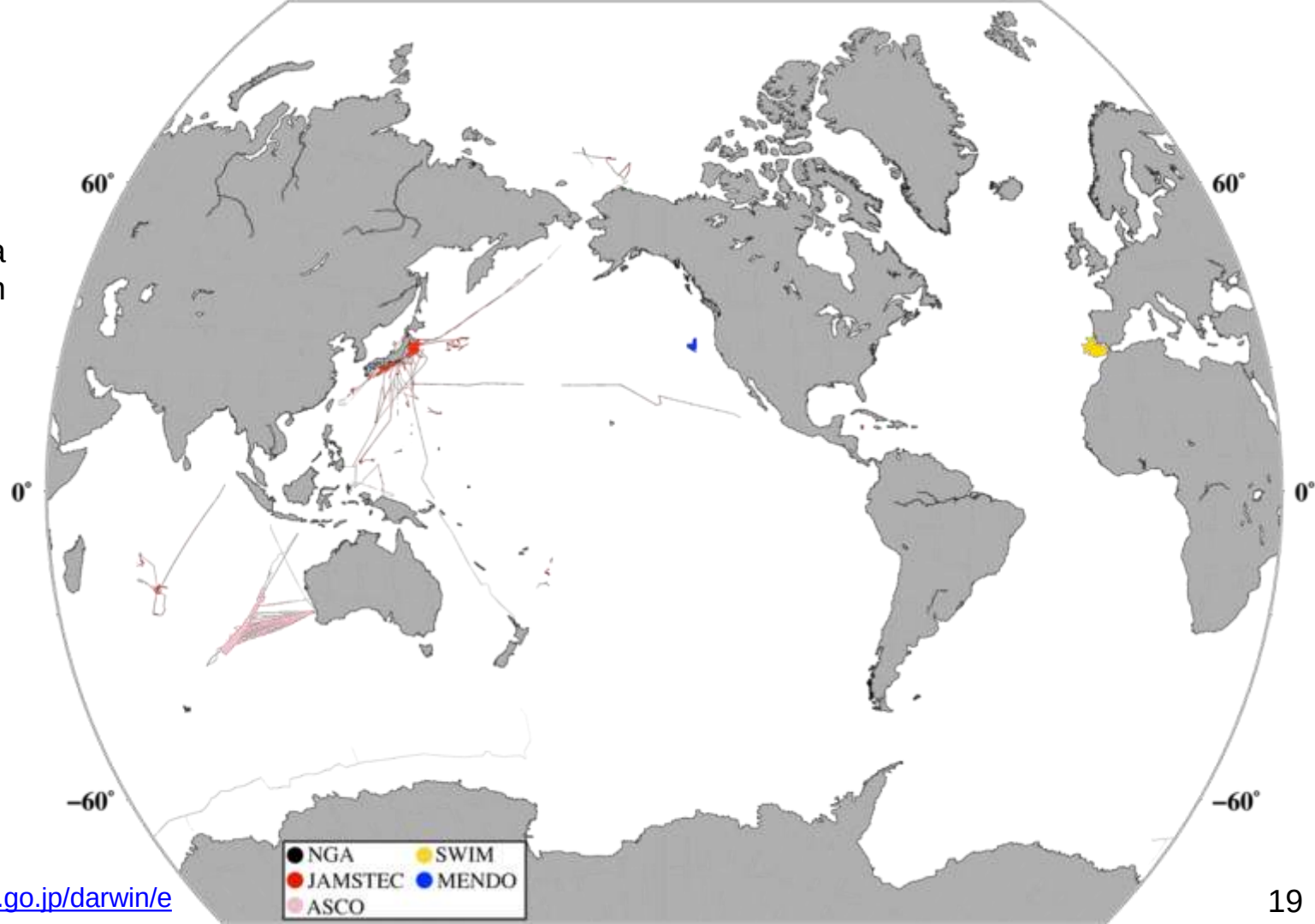
- High resolution
- ~ 278,000 km^2
- Excellent quality
  - No cleaning required



Source: Governments of Australia, Malaysia and the People's Republic of China, 2017. MH370 Phase 1 data. doi: 10.4225/25/595d7744b71e2

JAMSTEC

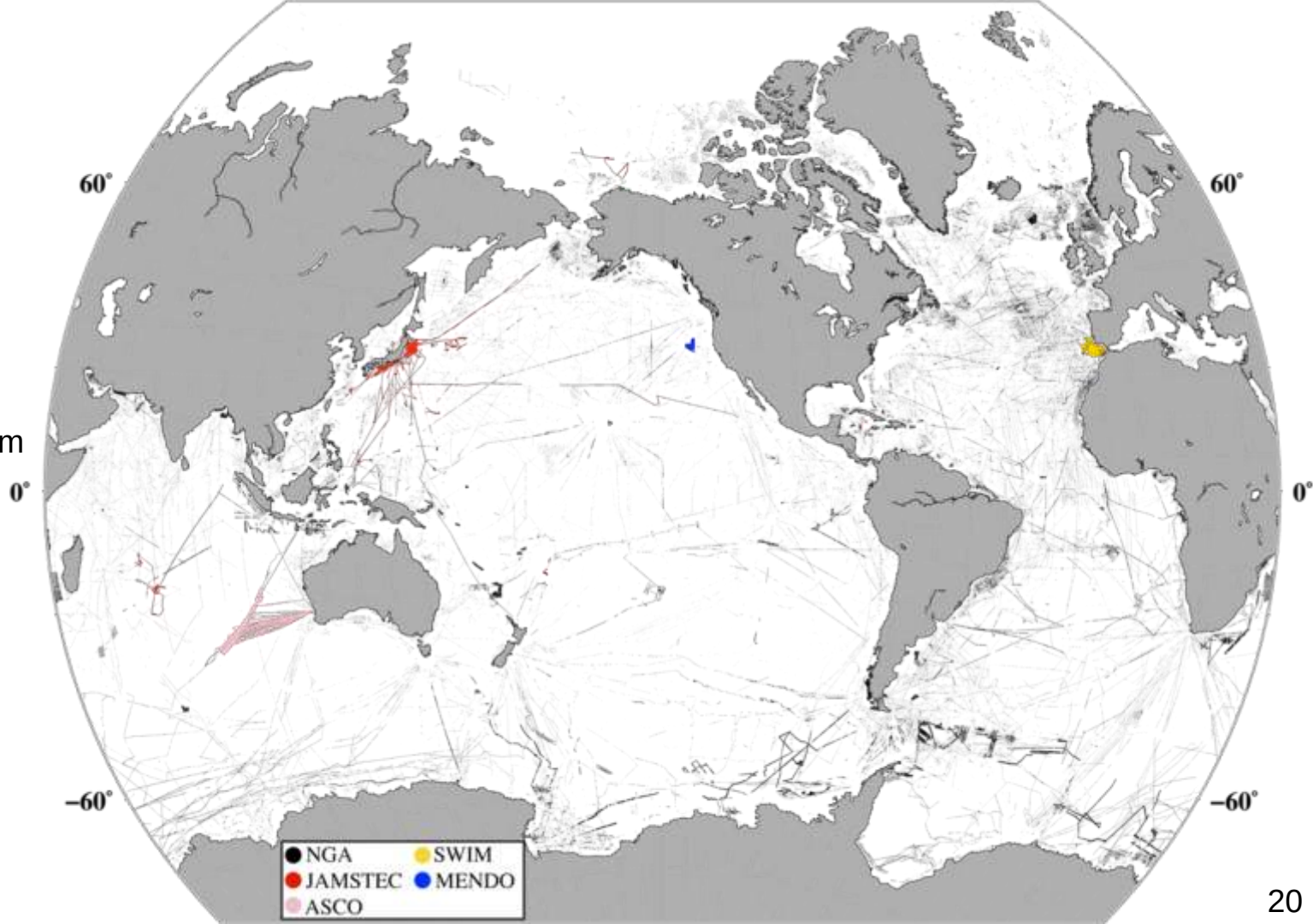
- All JAMSTEC data collected between 2014-2016
- Accessed from **DARWIN** explorer
- 25% increase in JAMSTEC data volume
- Cleaned data
  - Mostly excellent!

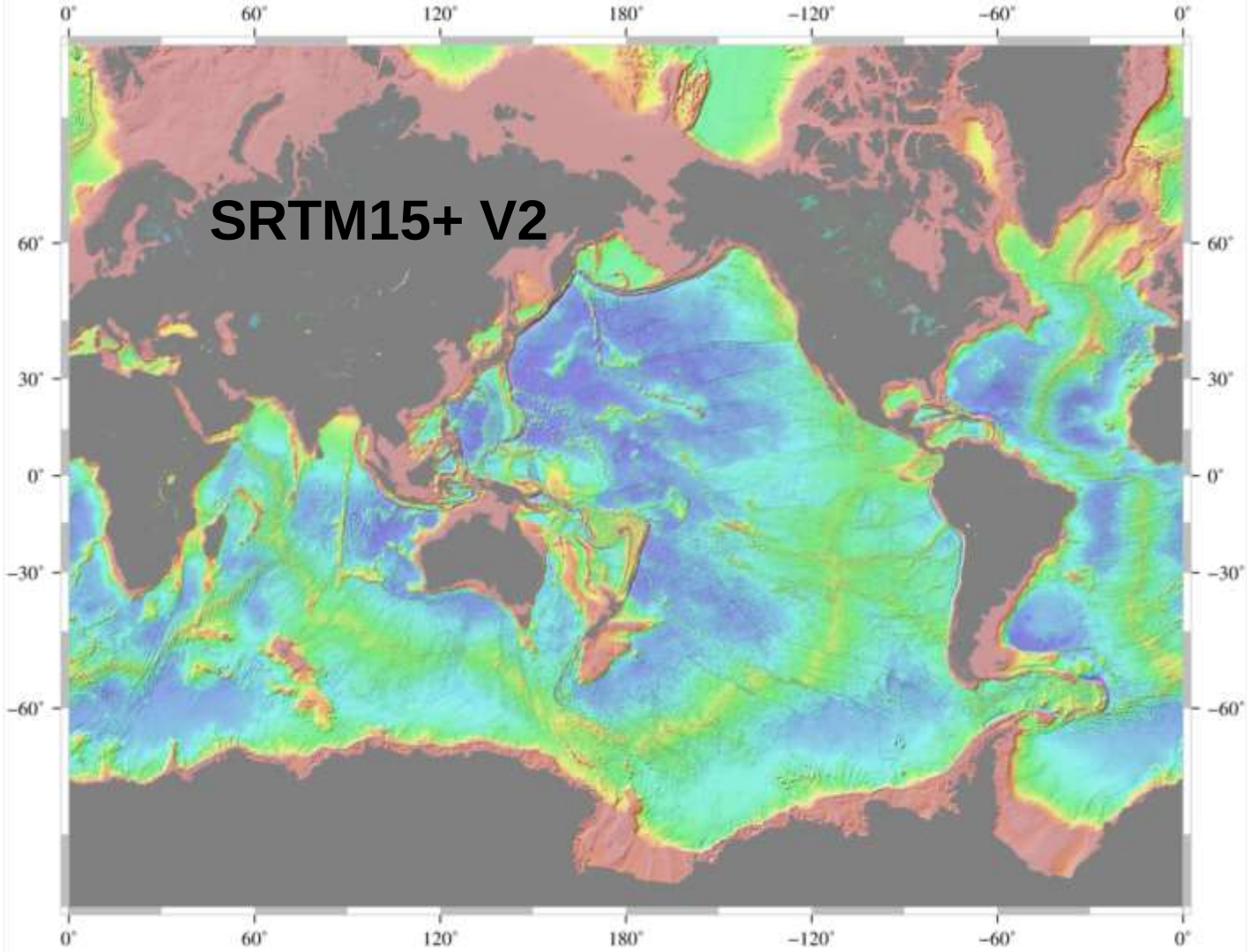


http://www.godac.jamstec.go.jp/darwin/e

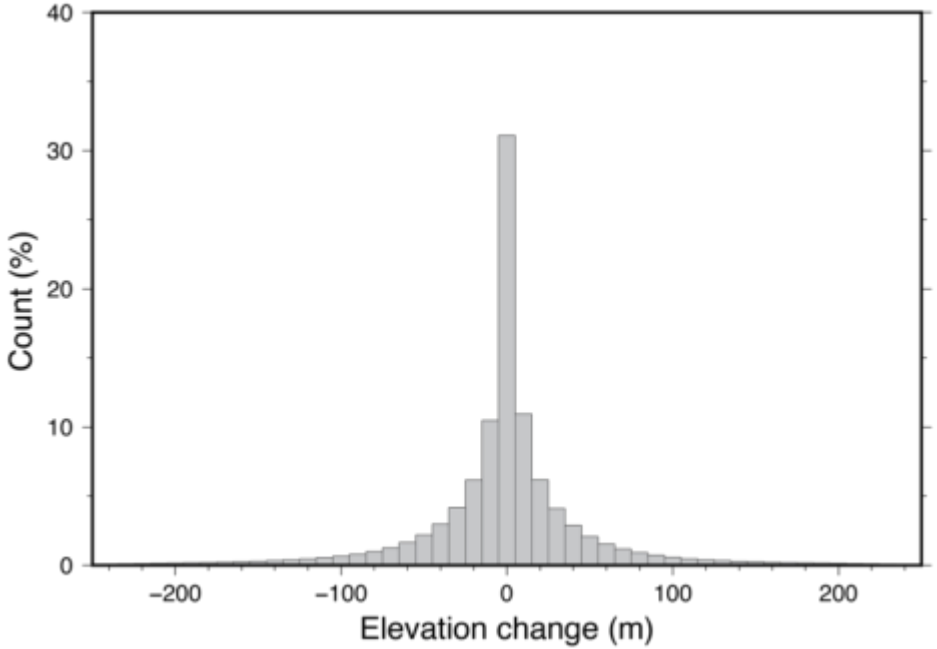
NGA

- *"Unclassified"* data supplied to us by James Beale (Pers comms, 2018)
- ~19 million new soundings > 2.3 km from an existing sounding
- Both multi- & singlebeam
- Mostly clean
- No Metadata

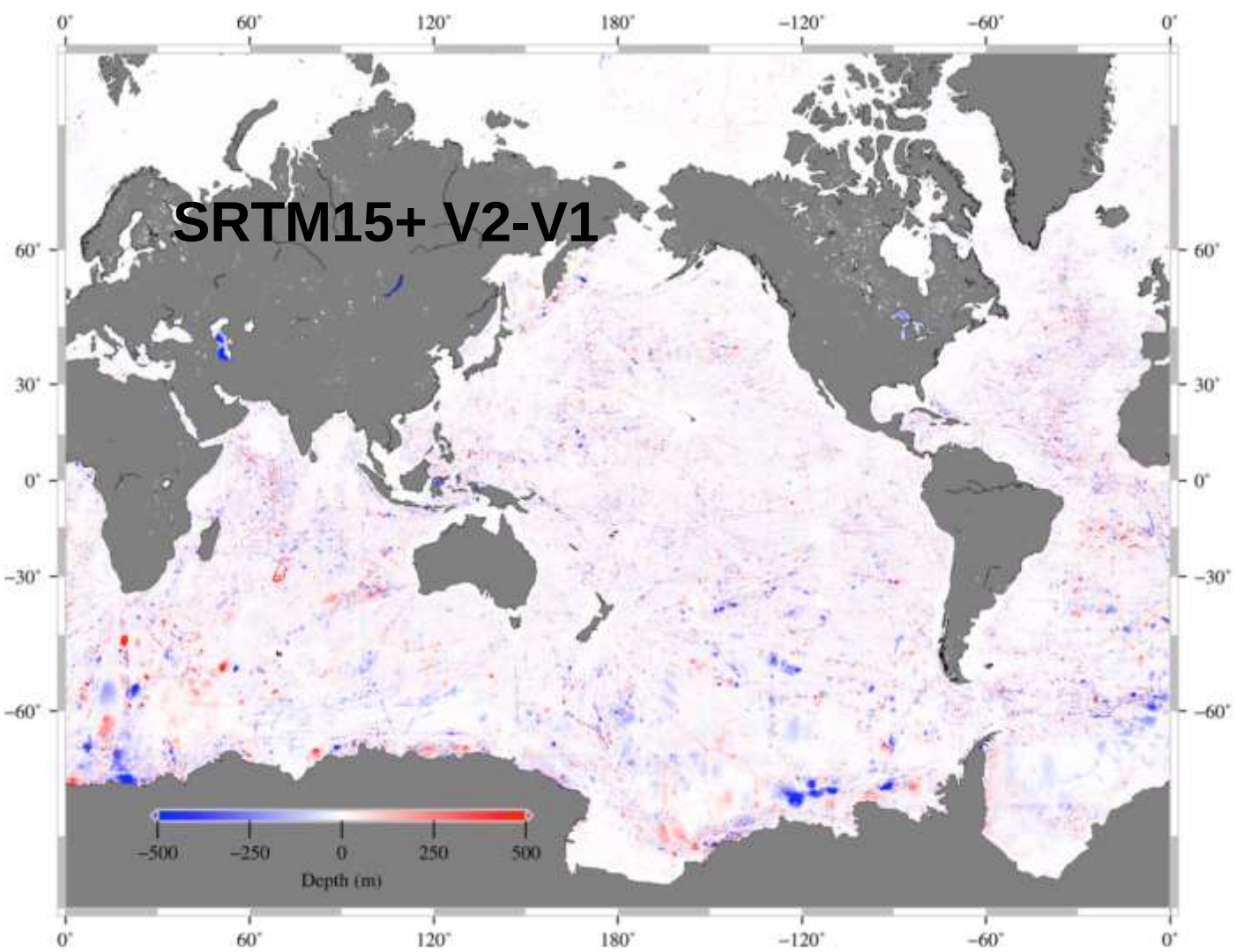



SRTM15+ V2
0°
60°
120°
180°
−120°
−60°
0°
60°
30°
0°
−30°
−60°

SRTM15+ V2-V1 global change



Statistic	Depth (m)
Mean	-1.83
Standard Dev.	61.8
Min/Max	-3953/3288


SRTM15+ V2-V1
0°
60°
120°
180°
−120°
−60°
0°
60°
30°
0°
−30°
−60°
−500
−250
0
250
500
Depth (m)

Future plans and integration

1. **Integration of SRTM15+V2 with latest GEBCO grid:**

   - We can supply either our “polished” grid (including soundings) or unpolished (no soundings) grid

   - However – these data would need to be open access/public domain.

   - Our updated SID grid (includes all new soundings at 15 arc seconds) may be useful for identifying the deep ocean “gaps” and provide a starting point.

Future plans and integration

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   - However – these data would need to be open access/public domain.

   - Our updated SID grid (includes all new soundings at 15 arc seconds) may be useful for identifying the deep ocean “gaps” and provide a starting point.

Future plans and integration

2. Making use of our new *PSQL* database

- This contains ~490 million “data points” (15s grid cells) used in constructing SRTM15+V2

- Contains all metadata we have (usually a reference link to the source)

Future plans and integration

3. Adding additional multibeam data into SRTM15+V2

- If you have any publically available bathymetry data that you think we may not have included and would like to share – please let us know!

Future plans and integration

4. SRTM15+V2 ***crowd sourced*** cleaning!

- A Google Earth .kmz file of our latest (draft) SRTM15+V2 grid is now available at: **https://topex.ucsd.edu**

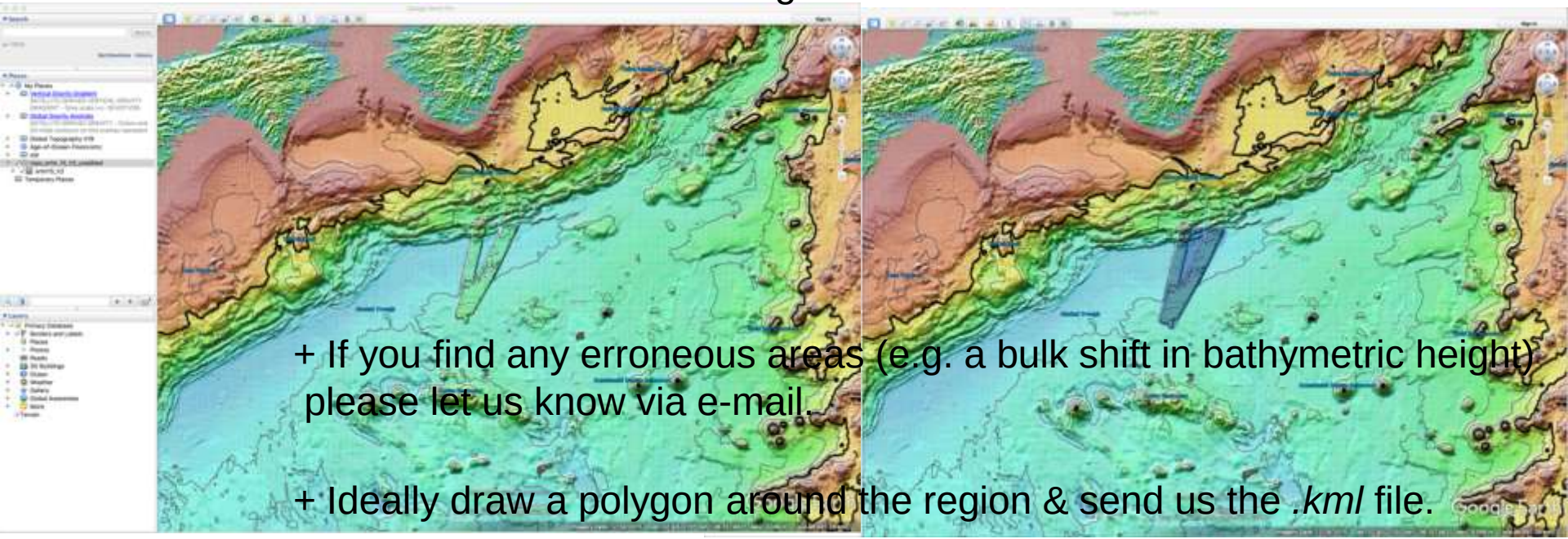
- If you're feeling generous.... please download it and take a look.

  + If you find any erroneous areas (e.g. a bulk shift in bathymetric height) please let us know via e-mail.

  + Ideally draw a polygon around the region & send us the *.kml* file.

Future plans and integration

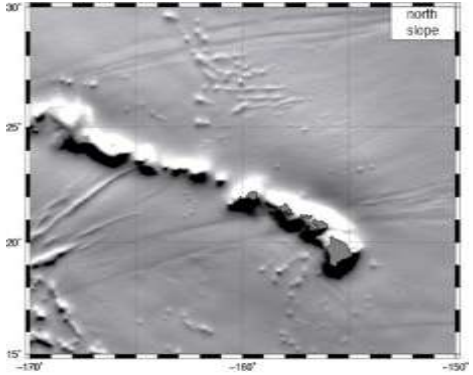
4. SRTM15+V2 ***crowd sourced*** cleaning!



https://topex.ucsd.edu

Part one

New satellite altimetry



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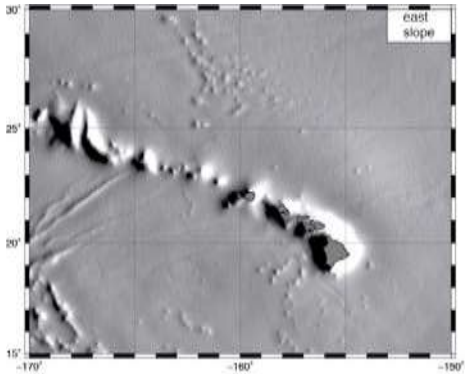

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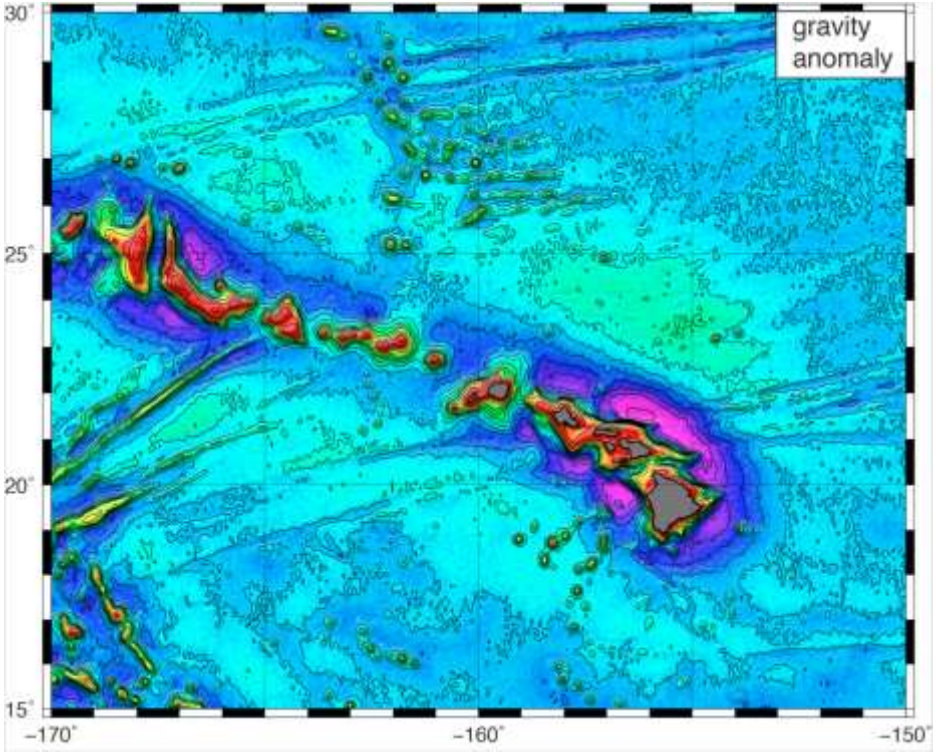
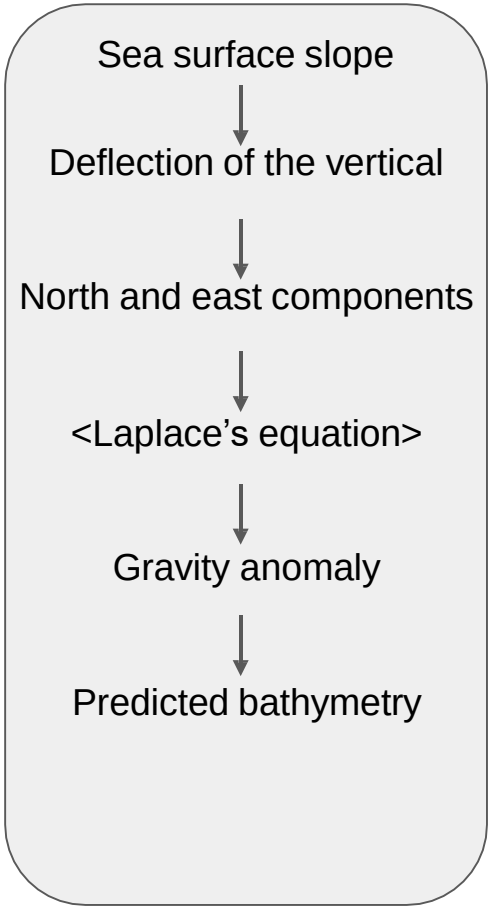


Satellite altimetry



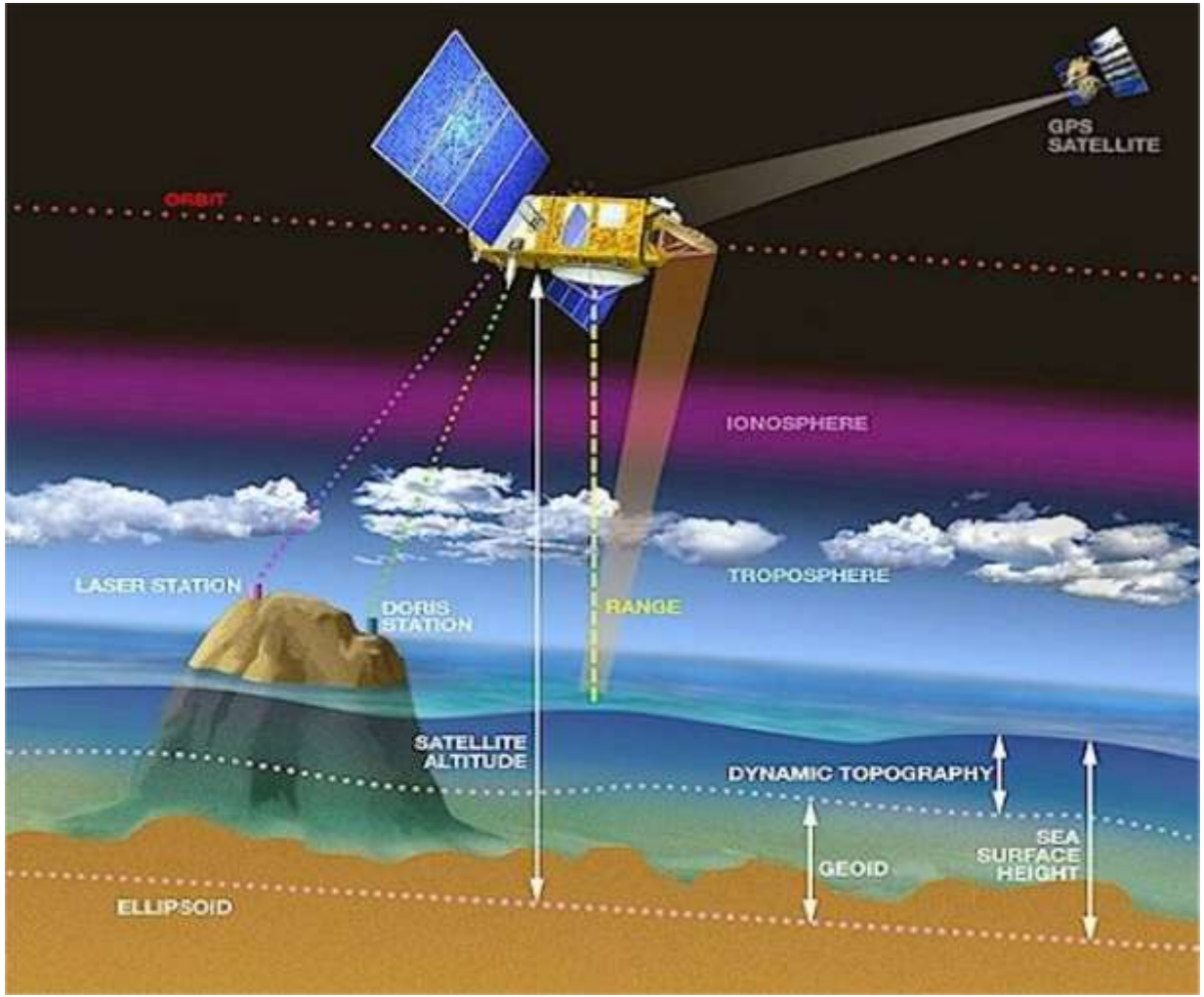


Figure from: http://www.altimetry.info/radar-altimetry-tutorial/how-altimetry-works/basic-principle/